

Status and ecology of the Barasingha (*Cervus duvauceli branderi*) in Kanha National Park (India)

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(With twenty-four text-figures)

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I INTRODUCTION

Despite the recent increase in literature it seems that the Asian deer species have been practically neglected. This is unfortunate, as many of these species are on the verge of extinction and a detailed knowledge of their ecology is required for long term conservation measures.

Descriptions on the barasingha (*Cervus duvauceli* Cuvier 1823) have appeared sporadically in hunting literature of the last century.

Blanford (1888-91) was however the first to give an account of the distribution of the species. Brander (1923) presented more information on the barasingha and made a distinction between the barasingha in northern India and those in Central India. Ellermann & Morrison-Scott (1951) subsequently distinguished two subspecies: *Cervus duvauceli duvauceli* Cuvier 1823 (Range: northern and northeastern In-

dia) and *Cervus duvauceli branderi* Pocock, 1943 (Range: Central India). The barasingha populations dwindled rapidly under heavy hunting pressure and the continuous habitat destruction effected by the increasing human population.

THE DEER AND THE TIGER by George B. Schaller (1967) based on a 14 month's pilot study on the tiger and its main prey species at Kanha gives the first systematic account of the barasingha's way of life. Schaller's study documented the precarious state of the barasingha in Central India, which incidentally led to considerations of this problem at the International Union for Conservation of Nature (IUCN) conference in Delhi in 1969. The Central Indian barasingha was practically confined to the Kanha National Park at that time. Yet Schaller's data had suggested that even this isolated population was threatened. Considerably less than 100 animals were left in 1964-65, and a mere 7 per cent fawns was obviously not sufficient to even maintain the population level. This and several other facts ultimately led to the formulation of this study. The essential goal was the determination of factors influencing the population size with subsequent reference to the ecological data collected by Schaller (1967).

Owing to the critical state of the population it was quite evident that no data from culled animals were to be obtained and considering possible disturbance or losses I could not mark the deer. These limitations were no doubt hindrances but on the other hand the barasingha of Kanha N.P. were an isolated popul-

ation. It could thus be assumed that the population was a discrete unit, which facilitated the work. The study lasted from April 1971 until April 1973.

1. Aims

An important question that was left unanswered by Schaller (1967) was the range of the population during the second half of the year. One objective of the study was therefore to determine the annual range of the barasingha. A second objective was to record activity patterns and relate those patterns to habitat structure and use in different seasons. A third objective was to identify factors limiting the population.

In order to pursue these objectives the population size and structure had to be determined. Owing to the drastic increase of the chital (*Axis axis*)¹ population in the past decade, the possibility of interspecific competition had to be tested. A habitat analysis was designed to indicate possible habitat alterations affecting the range conditions.

2. The Species

a) Past and Present Distribution

The barasingha² is indigenous to India. There is reason to believe that since historical times its distribution was confined to the northern part of the Indian subcontinent. Blanford (1888-91), Forsyth (1889) and Lydekker (1915) reported that the distribution during the last century extended along the foot of the Himalayas from upper Assam to Bahawalpur and Rohri on the Indus and parts of

¹ Scientific names of mammals occurring in the park will from this point on be omitted. They are listed in, Appendix III.

² "Barasingha" is a Hindi-expression that names the species according to the general antler pattern

of the stags: "twelve-pointer" (bara = twelve; singha = points). English: Swamp deer. In northern India the species is locally called "Gond" or "Gonda". The Kashmir stag or Hangul *Cervus elaphus hanglu* is also occasionally called "Kashmir barasingha" and may be confused with the species.

the area between the Ganges and the Godavari River, as far east as Mandla and as well as into the Sunderbans. The species could be found in marshy areas all over the Brahmaputra—Ganges—and Indus Basin, but not in the Himalayan valleys. However, it occupied the highlands of Central India. The southern most places that the barasingha was to be found were in the Bastar District in the State of Madhya Pradesh about 18°N. Essentially

the barasingha inhabited moist deciduous, semi-evergreen and wet-evergreen forests and the swampy planes of northern and Central India. It did not occupy drier areas (Fig. 1).

By the beginning of this century, the barasingha had completely disappeared from the western part of its range, i.e. the plains of the Indus River. Yet, no precise information on its distribution was obtained until 1967. According to the information collected by Schal-



Fig. 1. Past and present distribution of barasingha. Shaded area: Distribution at the end of the 19th century. Numbers: Occurrences mentioned in Table 1.

ler (1967) in 1964-65, the range of distribution had dwindled down to a few limited places in Nepal, Uttar Pradesh, West Bengal, Assam and Madhya Pradesh. Schaller estimated that approximately 3-4000 animals of *C. d. duvauceli* survived in 1965, plus 150 or more of *C. d. branderi* in Central India. Table 1 shows an account of the present situation.

barasingha herds were living in Uttar Pradesh only in the four divisions of Pilibhit, North Kheri, South Kheri and Bahraich.

The present situation of the barasingha in Nepal is not clear and needs further investigation. Schaller (1967) reported that about 400-1200 survive in 4 divisions of southwestern Nepal. At present it is said, that a larger herd

TABLE 1
PRESENT STATUS OF THE BARASINGHA

Place	Location in Fig. 1	Approx. Numbers
Northern subspecies (<i>C.d. duvauceli</i>)		
Uttar Pradesh:		
— Pilibhit Div.	1	
— North Kheri Div.	2	1800-2000
— South Kheri Div.	3	(Holloway 1973)
— Bahraich Div.	4	
Bihar:		
— Champaran Div.	5	perhaps a few
Assam:		
— Manas Sanctuary	6	a few (1974)
— Kaziranga Sanctuary	7	approx. 520 (Forest Dep. census 1972)
Nepal:		
— 3 Divisions in south- western Nepal (incl. Sukla Phanta Sanctuary)	8	400-1200 (Schaller 1967) recent status not available
Southern subspecies (<i>C.d. branderi</i>)		
Madhya Pradesh:		
— Kanha National Park	9	130-140 (1973, this study)

(1) Status of the North Indian barasingha:

Of the eleven localities mentioned by Schaller (1967) where barasingha were known or believed to survive in Uttar Pradesh, Holloway (1973) says, that eight of them "need to be struck for all practical purposes". The relatively small areas which contained suitable barasingha habitat only seven years ago, had either been turned into *Eucalyptus* spp. plantations or were lost to cultivation. In 1972

(about 1000 animals) is in the Sukla Phanta Reserve of southwestern Nepal. The number of survivors in West Bengal is not known. However, the small population of the Kaziranga Sanctuary in Assam was increasing in 1959, due to better protection (Burnett 1959).

(2) Status of the Central Indian barasingha:

Brander (1923) reported the presence of *C.d. branderi* in the Chindwara-, Mandla-, Raipur-, Balaghat-, Bilaspur- and Bastar Dis-

tracts of Madhya Pradesh and in the Chanda District of Maharashtra. But the distribution of the subspecies must also have extended into the States of Bihar and Orissa.

As far as one can tell from past records, its distribution was confined to the sal forests (*Shorea robusta*). Forsyth (1889) and Lydekker (1915) reported about the coincident occurrence of sal forest and the three species barasingha, wild buffalo (*Bubalus bubalis*) and red jungle fowl (*Gallus gallus*). A clear example of this is the former presence of both the barasingha and the red jungle fowl in an isolated patch of sal forest in the Denwa Valley near Pachmarhi (Fig. 1). Barasingha survived there until 1920, being isolated 250 kilometres from the western limit of sal, which runs through the Mandla District. Forsyth (1889) reported seeing "countless herds" near Mandla. Particularly the Banjar Valley had large numbers of barasingha. The beginning of the century then brought a crucial turning point in the distribution pattern of the barasingha in Central India. The wide valleys of the Narmada-, Mahanadi- and Godavari River and their tributaries were being cultivated. Herds were separated. Under the continuous pressure of hunters and local Gond- and Baiga-tribes isolated populations disappeared rapidly.

Records of the southern subspecies are scarce for the period between Brander (1923) and Schaller (1967). Although the latter obtained a piece of information saying that about 100 barasingha were surviving at the Madhya Pradesh-Orissa border between 1960 and 1965, it is doubtful whether by 1965 any

larger herd existed outside the Kanha National Park.³ Since then no barasingha were recorded in Central India except in Kanha National Park (Panwar 1973). However, Krishnan (1973) found a barasingha antler in Bastar District in 1970. Yet today it is very unlikely, that barasingha survive outside the Kanha N.P. in Central India. If they do they have very little chances of survival.

The distribution pattern of the species was very similar to that of the wild buffalo (*Bubalus bubalis*) in India. Daniel & Grubh (1966) state that both species depend on the same habitat. Both species suffered due to deforestation, but particularly due to cultivation of grassland and marshes.

b) Description

Schaller (1967) gave a fair description of the appearance of the species in different seasons and localities. As I later refer to the development of the antlers, I shall here restrict the description to the general pattern of the antlers and the seasonality of shedding.

The typical barasingha antler has a crown with 5 tines about halfway up the beam. Together with the brow tines, which often branch at almost a right angle, a total of 12 tines is achieved.⁴ Fig. 15 shows characteristic stages of antler development at different ages.

Record antler length was reported by Ward (1972) which measured 104 cm round the curve. Burke (1928) writes that a total of three record heads were obtained in Central India, all with 104 cm. In 1970 a pair of royal antlers was collected near Kanha. Its length round the curve was 92 cm. It numbered 17 tines plus 5 smaller buds, and the weight of

³ When searching for records one may often get confusing information about the presence of barasingha, which usually turn out to be either sambar or chital. Local people often consider all deer with antlers as barasingha.

⁴ Pocock (1933) was of the opinion that the pattern of tines among the antlers of different deer species is homologous. This was based on the theory of dichotomous branching: first of the base, which separates the brow tine from the beam and second

both antlers was 5.65 kg (Fig. 2).

The first stags which shed their antlers were recorded on May 17, 1971 and May 13, 1972. By the beginning of June, roughly half a month after shedding had started, about half of all stags seen in the Kanha Meadow area had shed. But it took another month for all adult stags to shed i.e. by the beginning of July. Stags with heavy antlers generally shed earlier than those with lighter antlers. The yearling stags were the last to shed their spikes. Some of them still had their spikes on as late as July 11. In the meanwhile, the heaviest stags had already grown antlers in velvet up to approximately 40 cm in length (Fig. 9). Occasionally, yearling stags were observed that still had their antlers in velvet in January and February. One case of a yearling stag was recorded that was in velvet until mid-May (i.e. at the assumptive age of 20 months).

The period of antler growth coincides almost exactly with the monsoon season that starts around mid-June. Both antler growth and monsoon cease in September. Thus, the period of antler growth falls into the period that is from the point of view of nutritive value of fodder plants, the most eutrophic. The velvet is rubbed off the antlers at the end of October and November.

3. The Habitat

a) Location and History

The Kanha National Park is situated be-

of the beam. This sequence of dichotomous branching, which according to Pocock, follows the same law in different species, then results in antler patterns with detectable homologue elements. According to him, the brow antlered deer (*Cervus eldi*), Schomburgk's deer (*Cervus schomburgki*) and the barasingha have a more specialized type of antler than the chital and sambar by an additional ramification of the beam, but are "clearly derivable from it." Those of the barasingha are more generalized

tween latitude 22°08' and 22°24' N and longitude 80°32' and 80°45' E in the Central Indian highlands which stretch from west to east through the State of Madhya Pradesh. It lies in the western spurs of the Maikal Hills which form the eastern branch of the Satpura Range. The present park area falls into the southern part of the Mandla District and the north-eastern part of the Balaghat District at altitudes between 502 and 802 metres. The park area drains into the Banjar River and its tributaries. The Banjar flows into the Narmada near the district town Mandla, 40 kilometres northwest of the park's centre.

The Maikal Hill Range was inhabited by two tribes, the Gonds and the Baigas. The practice of shifting-cultivation was widely used by them until it was prohibited in 1868. Many of the clearings in the park were caused by this. They served more or less permanently as sites for villages until the famine of 1874, when many of them were abandoned.

In 1935, 232 square kilometres were declared as an absolute sanctuary (excluding wild boar and birds), but in 1943 the western part of the sanctuary was again declared an officers shooting block, since it was feared that the pressure of browsing ungulates would hinder the regeneration of sal trees. In the remaining eastern part of the sanctuary (134 sq kilometres), the government permitted (1945) the destruction of 250 chital per year

on the average, but subject to greater variation (Pocock). Beninde (1937), on the other hand, supposed separate growth- and ramification potentials of the front and back part of the antler pole, which if unequal, may lead to a dominance of front directed tines, as in the red deer (*Cervus elaphus*) or backward directed tines, as in the barasingha. According to him, tines in different species would thus only be convergent structures.

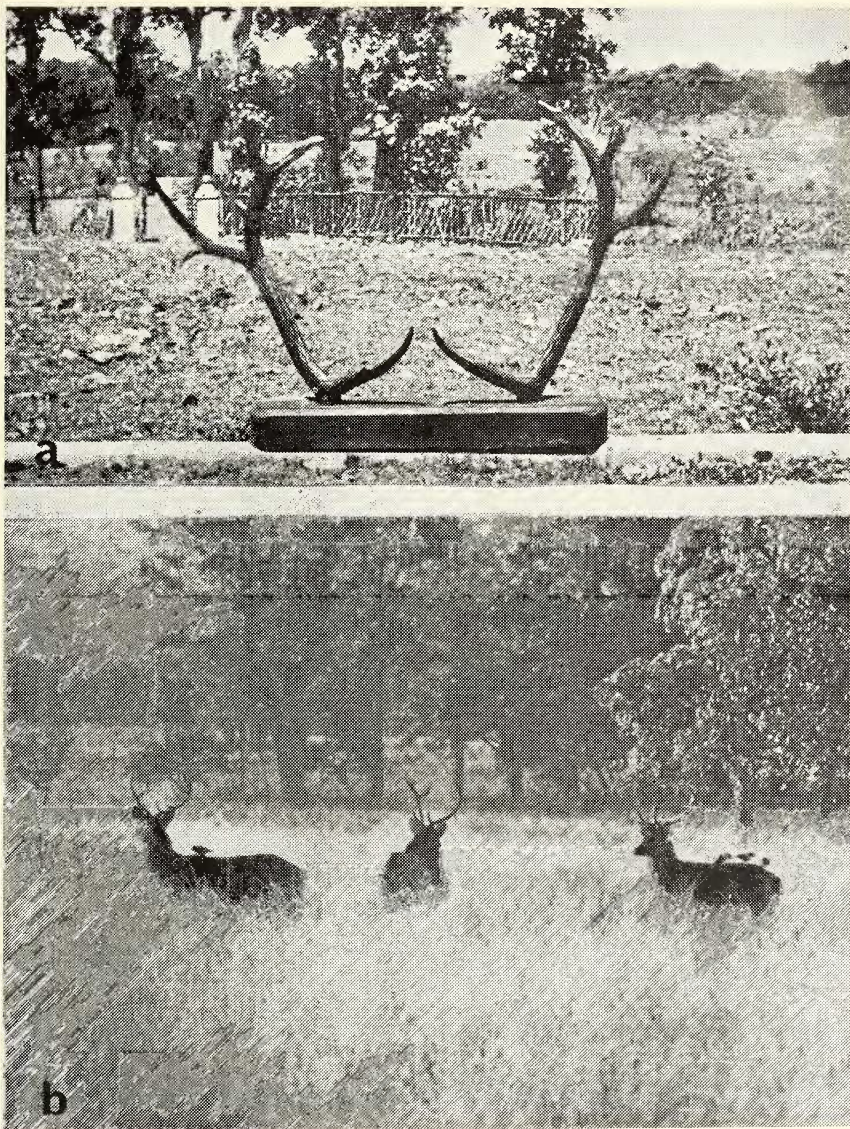


Fig. 2. (a) Royal barasingha antlers collected in Kanha in 1970. Number of tines 22. Weight of both antlers: 5.65 kg. Length round the curve: 92 cm. (b) Rutting barasingha stags on a misty January morning in the Kanha Meadow. Note: Common Mynas (*Acridotheres tristis*) on back.

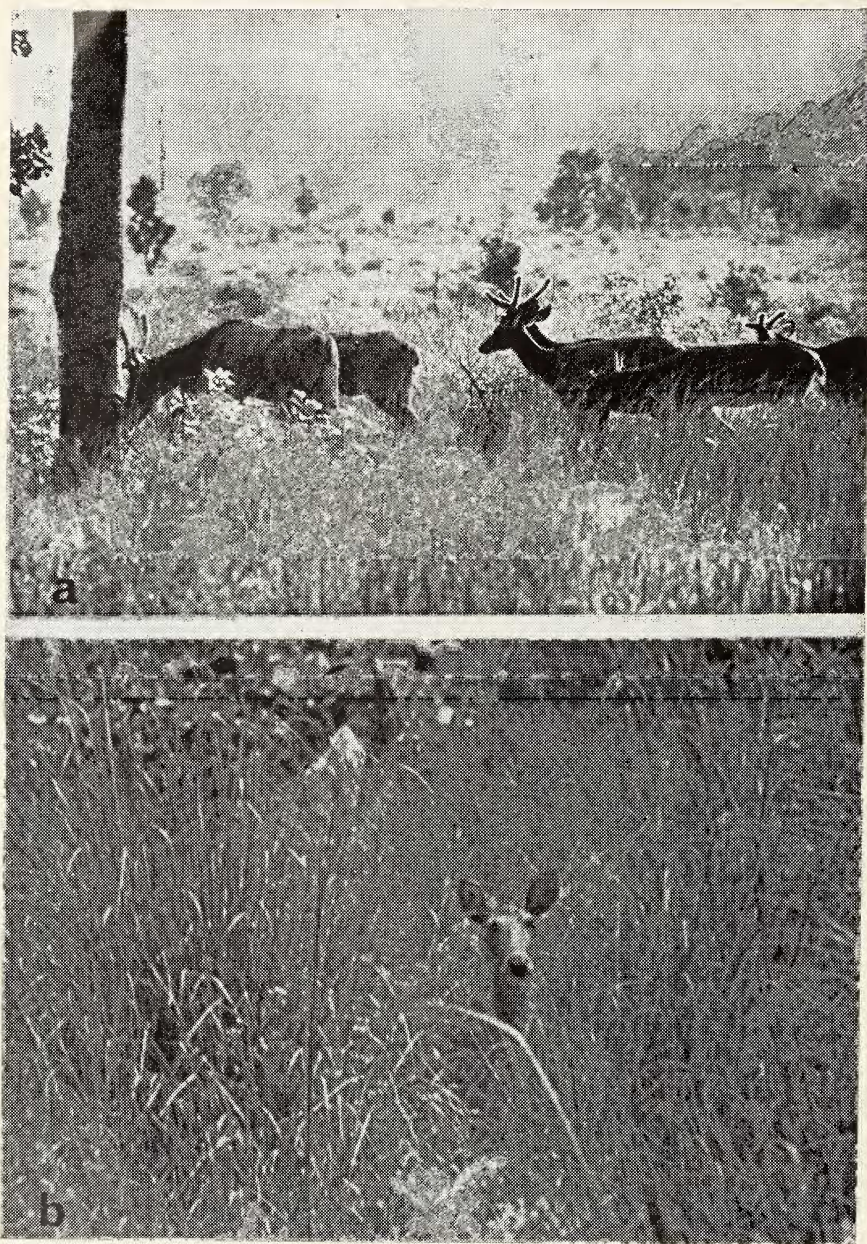


Fig. 9. (a) Stag group in the Sonph Meadow in July. Note: Summer coat and antlers in velvet. (b) Bedded barasingha hind in a swampy depression of a rivulet. September 1972.

to help sal regeneration. Between 1947 and 1951 the Maharajkumar of Vijayanagaram was permitted to shoot in and outside of the sanctuary. During that period he shot 30 tigers within a part of the present park area. In 1952 the sanctuary was again enlarged to 252 sq kilometres and shooting of any type was prohibited. In 1955 this area was declared a national park. In 1964 more land was added to the park enlarging it to 318 sq kilometres. In 1970 the part of the Balaghat District north of the Banjar River was joined to the southern part of the park, bringing it to the present size of 446.6 sq kilometres.

b) Tectonics and Geology

The principal formation is archaean which is also found in the rest of the peninsula. Gneisses, granites and schists (mainly mica-schists) and alluvial loamy soil, derived from decomposition of these rocks, form the undulating terrain on either side of the Mandla-Balaghat District border. This is the characteristic terrain of the wide valleys favouring sal forest. The most important meadows in the park, which retain most of the perennial watering places, are situated along these valleys. An underlying basalt formation, the decan trap, however, appears along the inter-district boundary of Mandla-Balaghat and encircles the park's centre i.e. the Kanha Meadow, with a ridge on three sides reaching altitudes up to 890 metres. It is frequently capped by the typical red laterite, forming flat ridge tops, locally called 'dadars'. These dadars are often free of tree-growth. As a result of weathering on the basalt, black cotton soil collects in pockets on both sides of the ridge.

c) Vegetation

The park falls into the distribution zones of the moist deciduous forest type. Rainfall is usually between 125 - 200 cm/year and there is a distinct dry season in contrast to the wet

evergreen forest type. Sal forest is considered to be the climatic climax for the main areas within the moist deciduous type (Champion 1948). Two principal forms may be found in the park:

(1) Sal forest:

Distinguished by the predominance of the sal tree *Shorea robusta*. It occurs on the undulating terrain, valleys and the lower slopes, principally on all low-lying alluvial soils of the park up to an altitude of 610 m. Sal was in great demand for the production of railway sleepers. The exploitation of sal trees in this area began in 1860 and it intermittently continued until 1959. A drought in 1942 caused the death of many sal trees and the sal borer *Hoplocerambyx spinicornis* also caused great damage. Champion (1938) classified the sal in Kanha as "peninsular moist low level sal."

(2) Mixed forest:

It covers the higher levels and slopes of the trap formations above 610 metres elevation. It is composed of about 50, mainly deciduous tree species. According to Champion's (1938) classification, the mixed forest in Kanha National Park belongs to the type: "Southern tropical moist deciduous mixed forest."

About 15-20% of the park's area are open meadows. Part of these are situated on the flat top of the ridge. A few smaller meadows occur on the hill slopes' terraces. The largest meadows however lie within the sal forest area. These are the meadows which were caused by the shifting cultivation of the Baiga tribe prior to 1868, as mentioned above. They lie in basins of the undulating terrain. The Kanha Meadow with its 6 sq kilometres, is the largest among them. A detailed description of the vegetation is given under intensive study in Chapter VII.

d) *Desiccation and Water Conditions*

After all the grasses go to seed in November, the grass cover in open areas dries fast. It remains partly green in shady locations and along rivulets. Fires occur in the winter months and induce early sprouts in the remaining tufts of perennial grasses. But even in unburnt areas green sprouts start growing slowly in the months of February and March. In early March the sal trees bloom. They shed their leaves which are simultaneously replaced by new ones. The other deciduous trees have also shed their leaves by then, but do not grow new ones immediately. Thus whereas the sal forest in the hills is bare. The great amount of water required to grow new sal leaves causes a sudden drop of the water table in sal areas and hence all the streams cease to flow. From March onwards water becomes gradually scarcer. Two types of pools that persist into the dry season may be distinguished:

- (1) Shallow tubs in the rocky or sandy bed of the larger streams (Sulcum-R., Surwahi-R., Desi-Nala), from where the water could not run off. Most of these pools dry up during the hot season. In the Surwahi-River e.g. there remains then only about one small pool per 500 m stream bed. Tribals used to catch fish by poisoning these pools with the bark of *Ougeinia cojeniensis*. They moreover become badly polluted by leaf litter and dead fish.
- (2) Pools that persist in small rivulets that transect the open areas. As the meadows often lie in flat basin that are surrounded by wooded hillocks, seepage water collects here even in the dry season. These pools contain clear water and rich aquatic flora and fauna, which indicate their perennial existence. On the slopes and banks of these rivulets

green grass grows throughout the year. The Kanha Meadow harbours, apart from others, around 65 pools of this type ranging in size from 3 to over 100 square metres. The majority of them is found in two rivulets, the Churi-Nala and the Menar-Nala. Sectionwise seepage water keeps running through these rivulets. Within the intensive study area such pools are found apart from the Kanha Meadow only in Sonph, where they are, however, few in number. These rivulets are of major importance as watering places and grazing ground for all kinds of wildlife during the dry season. In Chapter III-2 I shall describe the barasingha's movement pattern to these localities.

The water conditions have further been improved by damming up the Desi-Nala at the north western edge of the Kanha Meadow and a dam in Sonph. Further dams were constructed at the Menar-Nala as well as at the northern edge of the Kanha Meadow during the period of this study. A small perennial pond called "Shrawantal" is located to the east of the Kanha Meadow.

e) *Climate*

The park has the typical Central Indian monsoon climate with an average annual rainfall of about 1600 mm. A Forest Department record for Kanha reported 1602 mm in 1964. Mean monthly precipitation records for 1951-64 are available for Supkhar west of the park and Baihar south of the park (Fig. 3). About 95% of the total annual precipitation falls from mid-June to mid-October. The first monsoon rains in Kanha are expected around June 18. Pre-monsoon rains may occur irregularly in the first or second week of June. The heaviest precipitation falls in the months of July and August, and ceases in the month of

September. Winter showers occur sporadically and scantily from December through March. In 1971 heavy pre-monsoon showers fell which were followed by heavy monsoon showers. In 1972, however, the monsoon was late: There were no pre-monsoon showers whatsoever and until August 10, relatively little rain fell. In Maharashtra, Uttar Pradesh and in part in other Indian states, the irregular monsoon of 1972 caused a heavy crop loss.

The minimum and maximum weekly temperatures were recorded in the centre of the

Kanha Meadow (Fig. 3). Minimum temperatures measured in the forest were 1-3°C higher than those in the open during the cool season. From November through February, mist may accumulate during the night in the meadows. Heavy dew lies on the meadows in the morning regularly during this season (Fig. 2). In December and January night temperatures in the open occasionally drop to 0°C or even a few degrees below and ground frost may occur. Maximum day temperatures, however, remain above 25°C.

The hottest period of the year is from the end of April until the beginning of June, when the pre-monsoon showers arrive. Temperatures may reach 41°C and night temperatures often do not drop below 23°C. Due to late monsoon arrival, an unusually high temperature of 43°C was recorded in the third week of June 1972.

There are three distinct seasons in Kanha: The cool season (winter) from November to March; the hot season from April to June and the monsoon or rainy season from June to October.

f) Human Interference

Today only four of the clearings in the northern part of the park, i.e. in the Mandla District, are still occupied by forest villages: Kisli, Ronda, Silpura and Kanha. One village, Bahmnidadar, is located on the basaltic ridge. All of them are situated near the park boundary, except Kanha which occupies only a small part of the Kanha Meadow. In the recently added southern part of the park, i.e. in the Balaghat District, all of the clearings are at present still occupied by forest villages: Bishanpura, Sondhar, Aurai, Ghorela, Mukki and two small settlements.

Each of the clearings with a village contains grazing land for cattle and rice fields, from which one crop is harvested in Novem-

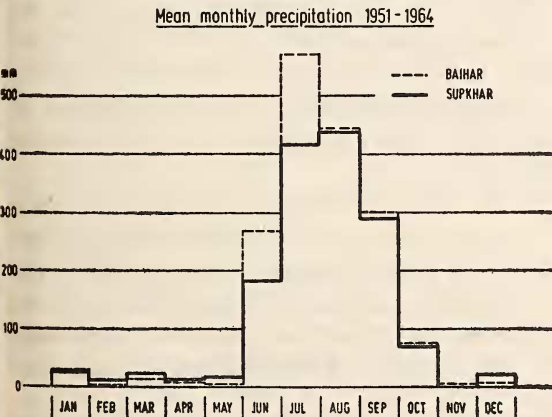
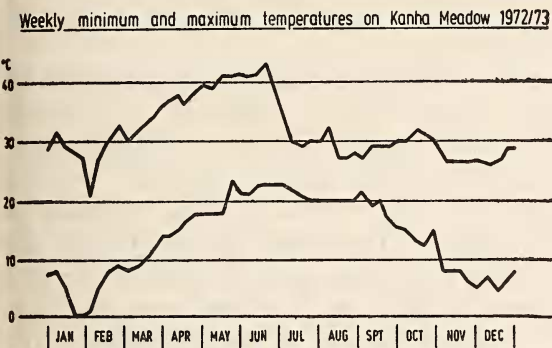


Fig. 3. Weather data, Kanha National Park. Temperatures were recorded 1.5 metres above ground in total shade. For the precipitation records I am indebted to the Forest Department.

ber. Until 1915 grazing was unrestricted in the forests and other clearings. During the dry season, villagers from outside the park area also used to bring their cattle to these areas. Today grazing is allowed on a limited area around the villages and no foreign cattle are allowed to graze within the park area. In 1969 the forest village Sonph was relocated outside the park. The Sonph Meadow and the meadows east and south of Sonph, i.e. Ornakhera, Parsatola etc., where cattle used to graze during the period of Schaller's study in 1964/65, are now left entirely undisturbed by either human or cattle activities. Today it is under consideration to remove three additional villages from the northern part of the National Park together with 5 villages situated in the southern part. Due to a relatively dense road net in the Kanha Meadow, the disturbance by tourists and villagers in that area has increased substantially over the last years.

(1) Poaching:

Occasionally tribesmen, mainly belonging to the Baiga tribe, enter the park from the south and roam about in the forests collecting fruit, mushrooms and roots, fishing and collecting fresh tiger kills and shed deer antlers. Active poaching, however is very rare. The effect of these tribal activities is insignificant as far as the direct influence on the wildlife is concerned. However, they often cause uncontrolled fires which may spread over large areas. Although during the study period special attention was paid to possible poaching with firearms, neither the Forest Department nor I could detect any activities within the park, however, there were some cases of poaching

and trapping outside. Within the last years, the Forest Department Staff has gained a very firm control over illegal grazing and poaching; whereas in the nineteen sixties, poaching must still have been an important factor.

(2) Burning:

Probably since the beginning of this century at least the Kanha Meadow was subject to annual burning during the cool season. Extensive—and annual firing of grasslands was practiced by the Forest Department until these methods were revised in 1972. Burning will again be considered in chapter VII.

g) Wildlife

The fauna of the park is representative of the Central Indian Highlands of previous centuries. However, elephants (*Elephas maximus*) and wild buffalo (*Bubalus bubalis*) were last seen in the area at the beginning of this century. The Indian gazelle (*Gazella gazella*) was also seen near the park in the past (Brander 1923). A list of the larger mammals occurring in the park is given in Appendix III. For mice and bats see Claude, 1973; birds: Guntert, 1973; and drosophilidae: Bächli, 1973.

Since 1953 the Forest Department carries out an annual wild-life census.⁵ Since I later refer to the interspecific relationship between chital and barasingha, the past development of the park's chital population shall be regarded here:

In 1935 about 2800 chital were tallied in the area. As mentioned earlier, chital were culled between 1945 and 1952. The reduced population remained more or less constant throughout the 1950's and until about 1965. Schaller (1967) found two

⁵ The census is taken in mid-June. About 50 forest guards with aids are distributed in delineated sections of the park, where they have to count the wildlife between fixed hours on two consecutive days. The mean of the two counts is taken as the

population for each species. In general, we may assume, that the Forest Department's census gives a fair idea of the population size of the large gregarious herbivores.

concentrations of chital in the park; one near Kanha, the other in Kisli. All together there were about 1000 chital in the park. Since 1965, the population has increased rapidly, and spread into the younger parts of the park. In 1972 there were 6-7000 chital which, most probably by now, have further increased. At present the chital is thus by far the most abundant ungulate in the park.

h) *Decline of the Barasingha Population*

The country-wide decrease of barasingha did not come to a halt at the boundaries of the park. In 1938 a Forest Department census yielded 3023 animals for the area of the present park. Since then the population has decreased steadily. The census of 1953 recorded 551 barasingha, and in 1970 there were merely 66 left. In 1964 Schaller (1967) counted 82 barasingha, and 55 in 1965. Even if considerable counting errors are taken into consideration, the low number of yearlings and fawns⁶ found by Schaller point to a population that was below 100.

In previous years poaching must have been intensive. The antlers—apart from their trophy value for sportsmen—were wanted by tribesmen for their supposed curative effect. Barasingha antlers were ground into powder and mixed with the extract of a *Euphorbia*-species. This mixture is said to have healing power against rheumatism, asthma, as well as other diseases (Panwar 1973).

In 1925/26 the park was beset by rinderpest. However, Brander (1923) writes that "the barasinghas are far more immune and suffer less casualties from rinderpest and foot and mouth disease than do sambar or bison." Schaller (1967) suggested that brucellosis might

have an effect on the population dynamics of the barasingha. Brucellosis causes early abortion of the foetus and would thus give a possible explanation for the low fawn rates found by him.

II FIELD METHODS

The primary techniques used throughout the study, that lasted 24 months, was direct observation. Barasingha were observed from a jeep which allowed approaching the deer to within less than 50 metres. Impassable areas were reached by foot. Due to the bias caused by the observer, I usually abstained from longitudinal observation. Records of dispersion, group composition and activity were made in time intervals of at least 4 hours along standardized routes through the Sulcum Valley. Other areas were regularly checked for barasingha also, and local people occasionally reported sightings. When possible, all observed barasingha were recorded as to sex and age, exact location, and activity, along with the time of observation.

Five sex—and age classes were distinguished: Adult males and females, yearling males and females, and fawns. Due to a limited fawning period, age classes were temporally separate by one year's periods, the above age classes hence being easiest to distinguish. According to the peak of the fawning period age classes were considered changing into the next older class on 15th September. Since groups were incoherent in time and space, the term "group" here refers to any temporary aggregation of individuals which at the time of observation were together and spatially separate from other barasingha. Regular census were carried out for the Kanha Meadow and the Sonph Meadow in intervals of 10 days throughout the year 1972. During and after the monsoon rains part of the areas had to be scan-

⁶ Yearling and fawn classes may be estimated relatively easily (see chapter VI—1).

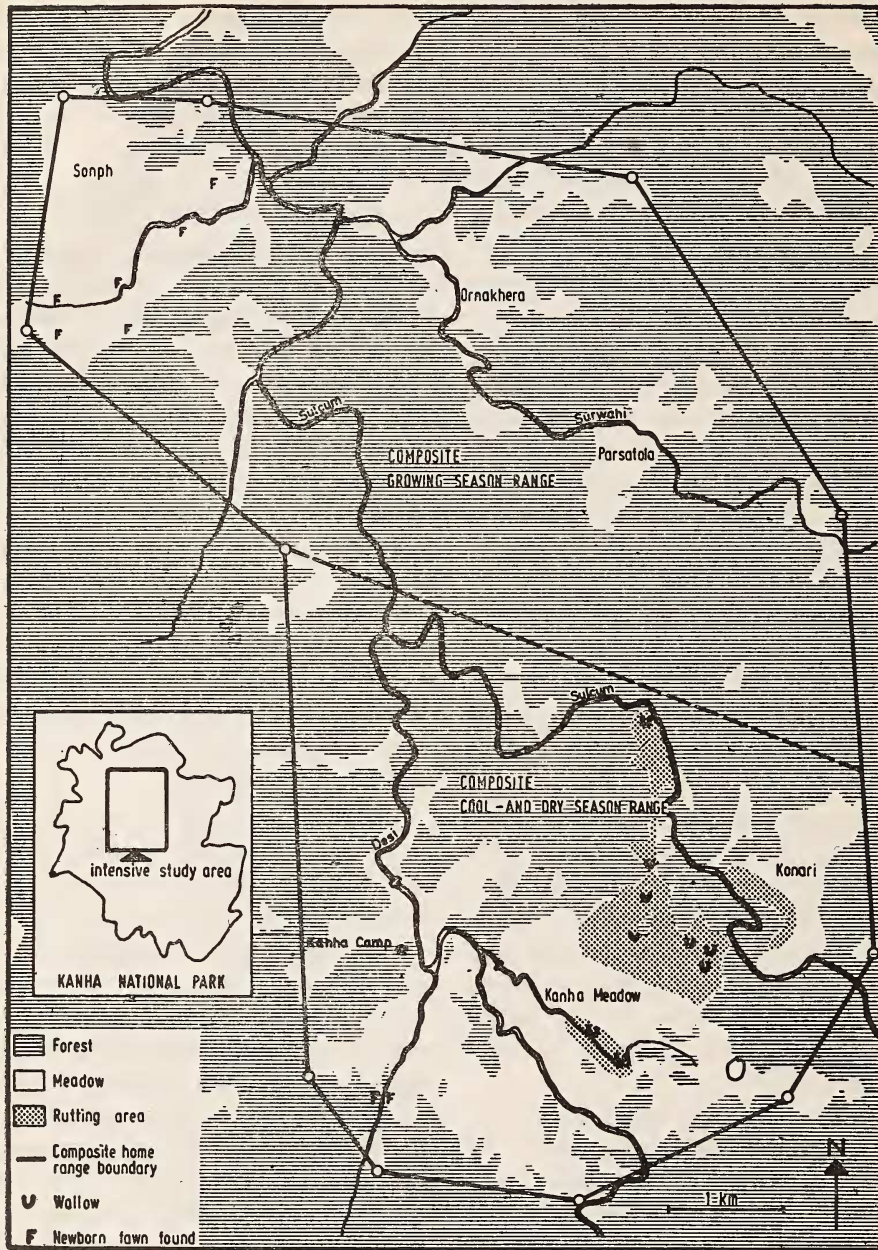


Fig. 4. Intensive study area with seasonal home range aspects of the barasingha population 1971-73.

ned on foot due to poor visibility and impassable roads. Annual total census were carried out with the help of the Forest Department Staff. They are described in Chapter VI-1.

Information on forage preferences was received by examination of feeding sites (Knowlton 1960). After a barasingha or a group of barasingha was observed feeding, I went to the feeding site and recorded instances of recent use. Each plant grazed upon was considered a single instance of use.

A rectangular area of 82 square kilometres that embraced the annual range of the population was chosen as the "intensive study area" (Fig. 4). Within this area the vegetation of the meadows was sampled using a grid system of sample plots. To test the hypothesis of common utilization of grassland habitat by different deer species, I used a modified pellet count technique which followed the principles stated by Neff (1968). To space out sample plots, distances were measured along compass lines in steps (Mean investigator's step = 0.816 metres).

Prior to the study, a 28 hectare-enclosure with carnivore safe wire mesh had been constructed in the western corner of the Kanha Meadow. It was designed for breeding barasingha in captivity, and was occasionally used for comparative observations in this study.

To describes seasonal aspects, the year was subdivided into 4 periods:

- cool season (December 15—March 14)
- dry season (March 15—May 31)
- early monsoon season (June 1—July 31)
- growing season (August 1—December 14).

All indications of time refer to the local time at Kanha (80°30' E). As base for the indication of locations maps on a scale of 4 inch = 1 mile were kindly provided by the

Forest Department. They were supplemented by own ground-surveys of the vegetational cover. The technical equipment consisted of 10 × 50 binoculars, a 15 to 60 × telescope and 35 mm cameras with a 200 mm telescopic lens.

More information on the techniques used are given in the respective chapters.

III RANGE OF THE POPULATION

1. The Composite Home Range

Initially it was planned to define the home ranges or seasonal ranges of individual barasingha. But the sparse sightings of individually known deer and the difficulty of their residence identification over longer periods excluded this. The efforts were then confined to locating the entire population's range:

Schaller (1967) recorded the barasingha in and around the park centre's Kanha Meadow during the rut and the following dry season. Their movement, however, remained unclear for the period from the beginning of the monsoon up until December. It was unknown even whether the barasingha remained within the park boundary during these seasons or not. Though for years the barasingha of the Kanha National Park were known to be the last in Central India.

I hypothesized that all of them belonged to the same herd and that this herd utilized a well defined area determined by environment and all biological requirements of the deer. This area will subsequently be referred to as "composite home range", or in the case of seasonal dispersion as "composite seasonal range". These terms were utilized also by Craighead *et al.* (1973) for elk (*Cervus canadensis*) groups in Yellowstone National Park.

The composite home range which encloses the points of all 689 sightings of groups and

solitary individuals recorded between April 1971 and March 1973 is shown in Fig. 4. The range boundaries were secured by joining the outermost points of locations (Mohr 1947). All other locations fell into meadows near the surrounding hills. There were no indications that barasingha enter deep into higher forest areas. It seems thus justified to connect these outermost points of locations with straight lines. According to the seasonal dispersion of the majority of the population, the composite home range was subdivided into a northern and a southern part of nearly equal area. Each of the two parts delimits a composite seasonal range. The composite home range embraces approximately 47 square kilometres and contains the major part of the parks' Sulcum River Basin. This range is practically coincident with the distribution of sal forest in the centre of the park (see Fig. 20). All of the larger meadows on the northern side of the basaltic ridge lie within the composite home range boundaries.

The peninsular distribution of the barasingha, as shown earlier, was largely confined to the moist deciduous forest climax. It appears that the predilection for a forest type persists even on the level of group dispersion: The mixed forest type occurring in the park above 610 metres elevation seems to lack the qualifications for utilization by barasingha in any one season. The same is true for continuous sal forest areas, as they are found in other parts of the park. Even in the past, unbroken sal forest areas were less frequented by barasingha than the park centre's sal area with its meadows. Thus there is reason to believe that it is not the forest type per se, that delimits the dispersal. Rather it is the rich type of meadow that may occur in sal forest areas. This indicates that the distribution of meadows within the sal area of the Sulcum River Basin

defines the composite home range of the present population.

a) *Dispersal*

Barasingha that obviously had left the composite home range were: one adult female reported from Bahmni Dadar (13 kilometres from Kanha village) in October 1972 and January 8, 1973; one adult male reported near Ronda (10 kilometres from Kanha village) on October 11, 1972; and one adult male reported near Mukki (16 kilometres from Kanha village) on March 15, 1973. The latter had crossed the park boundary, the two others had moved to within one or two kilometres of the boundary. Although these were rare reports, they suggest that emigrations from the composite home range occur in the period of monsoon movements (chapter III-4). Stragglers may leave the park and not return for the rutting period.

2. The Cool- and Dry Season Range

During the cool- and dry seasons (15th December to 31st May) the barasingha population congregated in the southern part of the composite home range. The range occupied included the Kanha Meadow and the neighbouring forest tracts north of the Kanha Meadow along the Sulcum River and the Desinala. From the 346 sighting points of groups and solitary individuals recorded during these seasons, merely 3 fell into the northern part.

The first congregations observed in the composite cool- and dry season range in December seemed to be related to the rut. Rutting behaviour was restricted to the cool season and occurred in well-defined areas of the cool- and dry season range in both the second half of the rutting period: on 28th January 1972, 70 animals; on 4th February 1972, 54 animals; and on 4th February 1973, 63 animals. Herds of this size contained approximately half the total population (see Table 8).

Breeding herd consolidations of the Kahha Meadow broke up into smaller units after the rut in March and April. Smaller groups and single barasingha dispersed from the Kanha Meadow and were occasionally observed in the forest tracts along the river courses, 1-3 kilometres north of this meadow. Individually known animals indicated that the barasingha moved about the southern range throughout the dry season. They occasionally appeared on the Kanha Meadow for varying amounts of time and left again for smaller clearings in the forest north of the Kanha Meadow. The occurrence of different sex-and age classes in two vegetational types during the cool- and dry season shall be shown in chapter V-2.

The occupation by barasingha of the largest

meadow in each of the two seasonal ranges was checked upon by regular censuses carried out in 1972. This, firstly, gave an idea of the seasonal utilization of the two meadows, and secondly, the census figures were a fair indicator for the seasonal occupation of the two parts of the composite home range. Censuses were taken in intervals of 10 days in the Kanha Meadow of the southern range and the Sonph Meadow of the northern range. Census were carried out in standardized tours through these open areas in the morning and evening of each census day. The maximum number of barasingha recorded on each day and in the two meadows is shown in Fig. 5.

Census figures point to peak aggregation of barasingha in the Kanha Meadow during rut

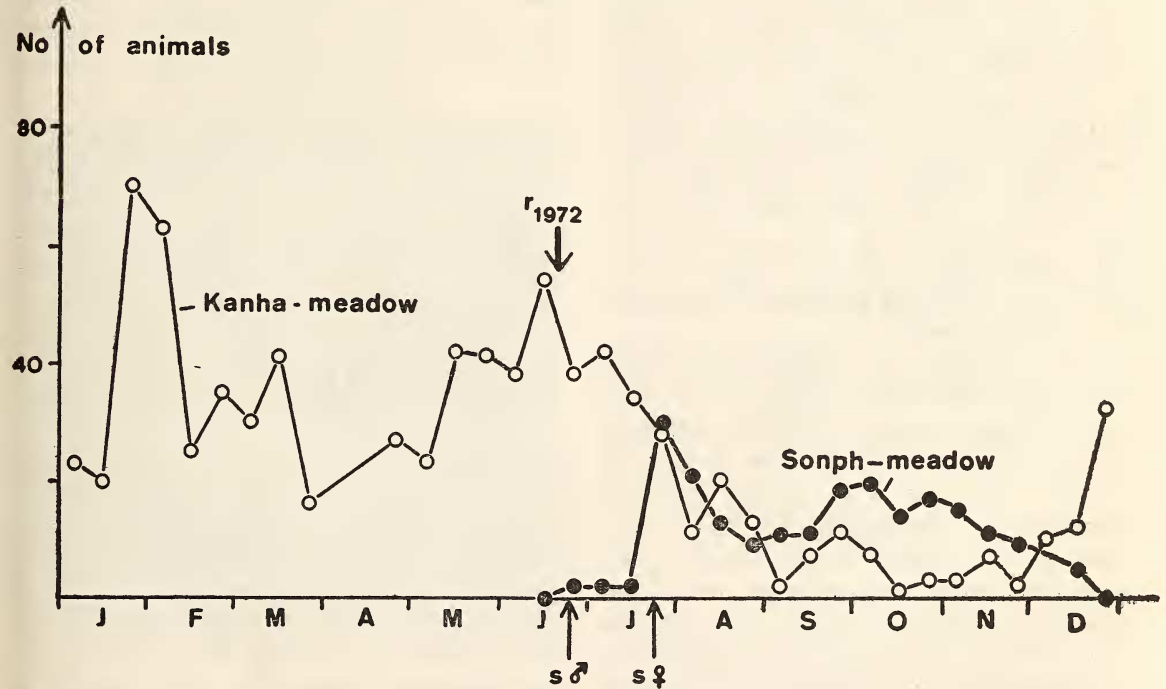


Fig. 5. Numbers of barasingha recorded on Kanha Meadow and Sonph Meadow in intervals of 10 days throughout 1972. s ♂ resp. s ♀ : First occurrence of males resp. females in the Sonph Meadow. r → onset of monsoon rains.

in January and February. Utilization of this meadow tends to decrease after the rut. It increases again with progressing drought until the onset of monsoon rains in June, when barasingha start moving to their growing season range in the north. This is indicated in Fig. 5 by decreasing numbers of barasingha occurring in the Kanha Meadow in July.

a) Activity during the Cool- and Dry Season

The most obvious factors governing activity patterns in deer are determined by the environment. Responses to environmental factors, however, depend upon the level of perceptibility or tolerance of the species towards these factors. However, constant environment is more likely to promote individual variability in activity patterns, whereas fluctuating environmental factors should produce more uniform activity peaks. Temperate climates were found to cause widely individual activity patterns in deer. For example, Craighead *et al.* (1973) found that elk (*Cervus canadensis*) in Yellowstone National Park are individualistic in such basic activities as feeding, bedding and moving.

Here, the patterns of these three activities shall be shown for the barasingha in its cool- and dry season range:

The conditions of observation did not often allow longitudinal recording of the activity of single animals. Another sampling method was thus used, recording in time intervals the activity of all animals visible on standardized tours through the Kanha Meadow and its vicinity. Activity records, thus, stem from observations of a number of unidentified animals seen during the cool- and dry seasons 1971-73. The total number of individual activity records for these seasons was 2862.

Fig. 6 shows the diurnal activity pattern into one hour periods. Pronounced peaks are

discernible for all three activities.

The main feeding activity peaks occur around sunrise and sunset. Already before sunrise barasingha start moving towards the

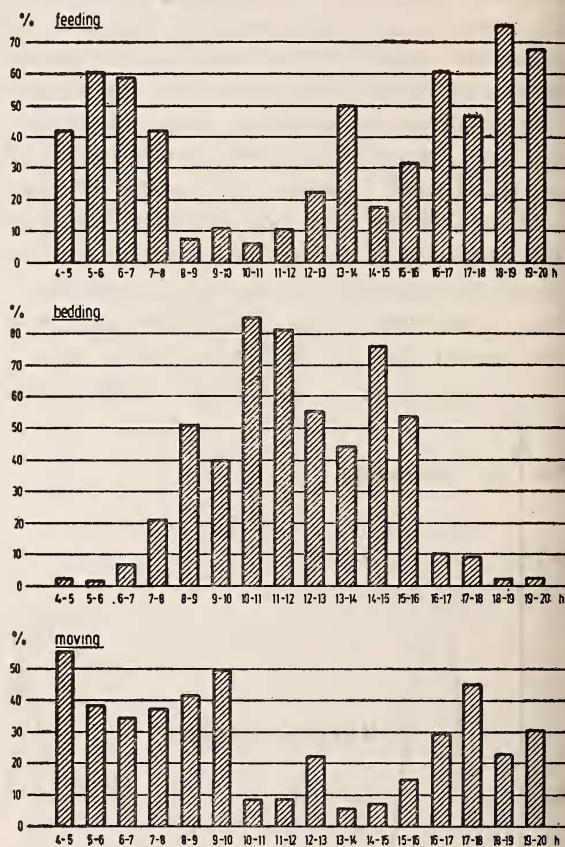


Fig. 6. Diurnal activity profiles of barasingha during the cool- and dry season (December 15 to May 31). Pooled classifications 1971-73 of three main activities. Sunrise between 0516 and 0643 hr local time at Kanha. Sunset between 1720 and 1840 hr local time at Kanha.

forest edges, or to feeding grounds along the rivulets of the open area, until movements come to an end around 10 a.m. Feeding activity is at minimum between 8 a.m. and 12 a.m., when most of the barasingha rest in the

shade of forest edges. Other animals stay in the meadow, where they bed in the shade of single trees of tree groves, often crowded together on the limited patches of shade. Occasional grazing activity starts again around noon, mostly in the shady resting areas. Other barasingha may move to the forest at this time. After resting in the hot hour between 2 p.m. and 3 p.m. feeding activity increases in the late afternoon. Between 4 p.m. and 6 p.m. groups enter the Kanha Meadow again from the forest and move to grazing grounds and watering places. The daily feeding maximum occurs then around sunset. Barasingha subsequently move to other grazing areas within the meadow. Sporadic observations and indications from Schaller (1967) suggest that the barasingha are sedentary around the major grazing areas within the meadow during night. Feeding activity may be continued from sun-

set until about 10 p.m. and fade to resting with intermittent grazing until morning.

On their movements between forest and meadow, the barasingha were found to cross the same areas daily, although they did not follow trails. Generally, barasingha moved towards the forest north of the Kanha Meadow in the morning and entered the meadow by the same areas again in the evening (Fig. 7).

As cloudy days during the cool- and dry season are few, the diurnal activity presented here may reflect the general pattern for clear days with hot hours around midday. The time when barasingha stopped, respectively started grazing in the open seemed to be determined by the heat or direct sunlight, whereas the time spent moving was largely given by the distance between suitable grazing grounds or watering places, and shady resting locations. The view, that climatic factors influence the timing of diurnal activity in these seasons, was supported by observations on the cloudy and rainy days, when activity peaks were less distinct and movements at minimum, due to bedding in open areas. The influence of the temperature regime on the timing of the daily feeding activity of deer was suspected even in temperate climates by Cowan (1945), Leopold *et al.* (1951), Swank (1958), Taber & Dasmann (1958) and Loveless (1957). Linsdale & Tomich (1953) stated also that deer may make adjustments in form of short distance movements within their principal habitat to meet with requirements for shade.

b) Factors influencing Utilization Pattern

Many habitat types may occur within a home range, yet, an animal may utilize only a few of these. Preferences for certain types of habitat can be due to food preferences, cover, or other factors. Berg & Phillips (1973) found such "habitat preferences" in moose (*Alces alces*)

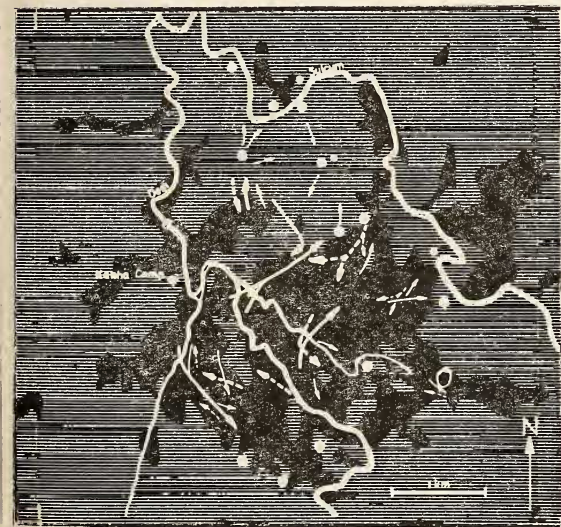


Fig. 7. Daily movement pattern of barasingha in the Kanha Meadow area, during the cool- and dry seasons 1971-73. Dots: Main day resting areas. Arrows: morning routes. Dashed arrows: evening routes.

of northwestern Minnesota.

The regularity with which the barasingha moved to feeding areas of the Kanha Meadow during the cool- and dry season intimated such preferences for certain types of habitat. A possible reason for this could have been the widely different grassland structure in different parts of the Kanha Meadow. It will later be demonstrated that high ungulate grazing pressure is correlated with the occurrence of certain grassland communities during the growing season.

However, in May 1971 it appeared that water and burning were such powerful factors that preference for certain types of grassland during the cool- and dry season were eliminated. Grazing activity in the Kanha Meadow seemed to be largely restricted to rivulet zones and patches of unburnt grassland. Thus, in the cool- and dry season of 1972 an attempt was made to check upon the influence of rivulet zones and unburnt patches on the selection of grazing areas.

The data used for this investigation was based on interval records of unidentified animals seen on standardized tours through the Kanha Meadow. Records originate from the period between January 22, 1972 (one week after burning) and June 21, 1972 (first monsoon rains).

A grid system (400 × 400 steps) was superimposed on the map of the Kanha Meadow prior to the investigations. It divided the area into 61 squares. It was noted whether each square contained perennial water or unburnt grassland or both. Subsequently the frequency of grazing barasingha groups seen in each square was recorded. While recording groups instead of individual barasingha, bias caused by group size was avoided. Group size could at least partly be stipulated by social factors. Graz-

ing groups were marked by grazing activity of all group members and hence absence of movements. The total number of such records for the period concerned was 102.

TABLE 2

MEAN FREQUENCIES OF GRAZING BARASINGHA GROUPS IN 4 TYPES OF SQUARES OF A GRID SYSTEM 400 × 400 STEPS SUPERIMPOSED TO THE KANHA MEADOW. ONE WEEK AFTER BURNING UP UNTIL ONSET OF MONSOON 1972

Kruskal-Wallis Test:

$$H = 19.71 > 16.27 = \chi^2_3; 0.001 (p < 0.001)$$

Squares containing:		Number of squares	Number of groups	Mean per square
Perennial water	Unburnt grassland			
—	—	34	13	0.38
+	—	22	37	1.68
—	+	19	37	1.95
+	+	6	15	2.50

Table 2 shows that the mean number of grazing groups per square is lowest for those squares that contained neither perennial water nor unburnt grassland. It is medium for those squares that had one out of the two qualities and highest for the squares that had both qualities. A Kruskal-Wallis-Test proved significant differences among the four samples. Thus, during the cool-and dry season, grazing activity centres in the Kanha Meadow are primarily distinguished by these gross physiographic features of the grassland. They consequently influence the direction of the daily movements. Whereas the principal movement pattern is out of the meadow in the morning and into it in the evening, the movement within the meadow is determined by the location of perennial water and unburnt grass zones.

The preference for areas that harbour perennial water does not necessarily mean, that the site is selected for grazing due to the possi-

bility for drinking. There may still be a preference for certain forage species, which occur near perennial water. This is undoubtedly the case with *Saccharum spontaneum*, a preferred forage species during the cool-and dry season. It forms dense stands along rivulets and produces green sprouts continuously in these locations even in the driest period of the year.

Extensive burns may cause starvation among barasingha. Green sprouts that occur after burning wither soon or are grazed upon by the large herds of chital, and cause only a shortlived attraction to barasingha.

Acute food shortage became evident when an accidental fire swept the grass cover and sal forest undergrowth of the entire 28 hectare-enclosure on March 25, 1972:

To lessen the critical situation to the enclosed deer, cut grass was deposited in the enclosure and trees were lopped. Young sal leaves that were killed off by the heat of the ground fire and subsequently fell from the trees supplied further forage. The enclosed chital turned to browsing from loppings and withered sal leaves readily and seemed not to be affected by the food shortage. Yet the barasingha made no attempt to seek forage. Most of the time they simply stood in a serried group or moved up and down along the enclosure fence. One week after the fire all 7 barasingha enclosed at that time, showed severe signs of malnutrition.

3. The Growing Season Range

Schaller (1967) stated that the barasingha disperse from the Kanha Meadow during monsoon and remain concealed until the beginning of the rut in December. Fig. 5 shows that the numbers of barasingha that were counted in the Kanha Meadow in 1972 decreased after the onset of the first monsoon rains. Throughout August and until mid December (growing

season) the numbers of barasingha staying in the Kanha Meadow never exceeded 21 animals, whereas higher numbers were recorded in Sonph, which is the largest meadow of the northern part of the composite home range. This suggested (1) that a majority of the barasingha leave their cool-and dry season range in the south during the early monsoon season and (2) that not the entire population confines its activities to the same part of the composite home range. However, in spite of the wider dispersion during the second half of the year, distinct concentrations occurred in the northern part. A mere 22 per cent of all 229 locations of groups recorded during the growing seasons 1971 and 1972 fell into the southern part. Fig. 8 shows the distribution of groups during those periods of the population's most distinctive polarization in one of the two parts of the composite home range. They are coincident with the peak of the rut in January and the late fawning period in October.

a) Importance of the Sonph Meadow

The Sonph Meadow (Fig. 9) had been occupied by a forest village, its rice fields and grazing grounds for cattle until the village was relocated outside the park in 1969. Today merely the collapsed dikes of former rice fields and local predominance of *Ischaemum indicum*—a grass species indicative of heavy use by cattle—still point to the former presence of a village. In its present condition the Sonph Meadow had a more heterogenous grass cover than other meadows in the park (Fig. 20). It is distinguished by a patchy distribution of grass species and grassland "facies", induced by the patterns of former rice fields.

Sonph was referred to as being one of the best areas to see barasingha at the beginning of this century (Nath, not dated). However in 1964-65 Schaller (1967) recorded no bara-

singha in Sonph and the Forest Department had not recorded them in this area for many years (Panwar 1973). This was prior to the relocation of the village in 1969. Yet during my study period barasingha were sedentary in the Sonph Meadow throughout

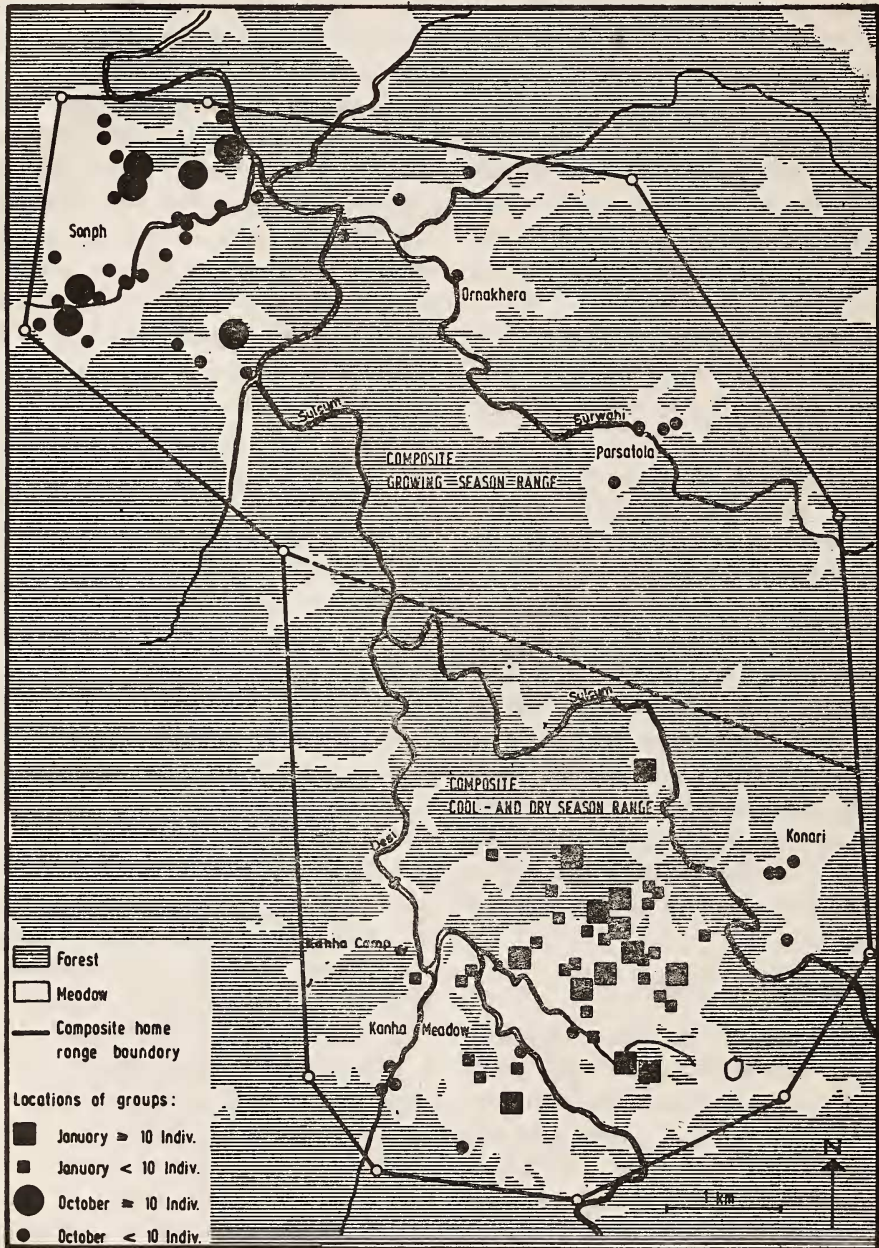


Fig. 8. Sighting points of barasingha groups during the periods of the utmost polarization within the composite seasonal ranges. From pooled classifications January 1972 plus 73, and October 1971 plus 72.

the second half of the year. The largest groups ever observed in the northern part of the composite home range, were recorded in this meadow. It has been suggested that the grassland structure that evolved in Sonph after human influence was banned, probably meets in ideal ways with the requirements of the barasingha during the growing season (Martin 1973).

Sonph was moreover the major fawning area. Six out of eight newborn fawns found during the study period were found in this meadow (Fig. 4).

b) *Activity during the Growing Season*

With the onset of monsoon rains and the subsequent appearance of new sprouts, the daily activity pattern of the barasingha changed markedly. Cloudy days, abundance of green forage and water permitted them to be more sedentary within open areas. This became even more evident during the growing season, after the majority of the barasingha had travelled to the northern part of the composite home range. Although the population had attained a wide dispersion, the activity of groups and solitary individuals seemed to be restricted to rivulet zones within the various meadows throughout the growing season. Periodic daily movements, as they were observed during the first half of the year, did not occur and barasingha very rarely entered the forests. Feeding- and bedding areas coincided along the tall grass of rivulets. Diurnal activity was restricted to short bouts of grazing. Most of the day was spent lying down in tall grass areas and grazing occurred in the direct vicinity of the bedding site. On cloudy days grazing intervals of up to 10 minutes length occurred throughout the day with a slight peak of grazing activity around sunset. The sunny days following the

end of the monsoon rains then caused a polarization of several grazing intervals around the period of sunrise and sunset.

The tendency to remain in tall grass zones seemed related to (1) the need for shelter, and (2) the abundance of highly palatable food and water in the direct vicinity of the bedding sites. All sex- and age classes were found to behave in the same way. Thus sedentariness was not merely related to separation for parturition.

c) *Distribution of Bedding Sites*

Bedding sites of barasingha were found to have a typical appearance: The grass cover, while in its growing stage, was crushed into the soft ground by the bedding animal. This hindered the grass coming up again, which was also augmented by the repeated use of the same beds. The sites where barasingha had bedded ultimately were distinguishable from other species' beds by an oval patch of more or less bare to muddy ground which always had hoof impressions. Most of these beds persisted into the cool season.⁷ As bedding and feeding areas were coincident, locations of such beds helped to check upon the principal habitat of growing season activity centres (Fig. 9). The 28 hectare enclosure was used to this purpose, as it contained all major components of the barasingha habitat, i.e. sal forest, open grassland, loose stands of tree and rivulet zones. Seven barasingha were living in the enclosure in 1972. The number and distribution of their growing season beds was recorded on November 10, 1972 (Fig. 10). The total number of beds was 112. 95 per cent of them were within 35 metres of the rivulet, and 21 per cent of all beds were less than 5 metres away, or on banks within the rivulet.

⁷ The flight distance of bedded barasingha was unusually short during the growing season. It was not uncommon, that barasingha were approached

to within less than 10 metres before the animal rushed out of the grass and bedded again some distance away.

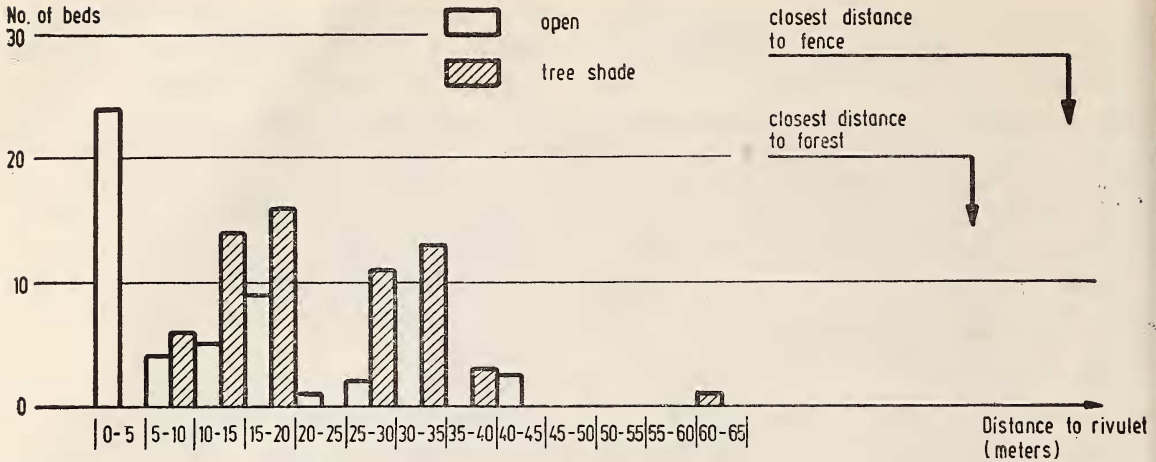


Fig. 10. Distribution of barasingha beds in relation to rivulet of the enclosure. Records from growing season 1972. The representation assumes equal distribution of shade giving trees with the distance from the rivulet (see text).

More distant ones were predominantly located under trees, but practically no beds were situated outside the rivulet zone. The distribution of shady bedding sites in Fig. 10 is of course dependant also upon the availability of shade giving trees. The distribution is therefore not merely a variable of the distance to the rivulet. Trees also occur in zones more distant from the rivulet where no or few bedding sites were found. The tree density was hence assumed to remain equal with the distance from the rivulet.

Some beds may have occurred also in the forest. Due to the absence of a continuous grass cover, beds could not always be distinguished here. However, direct observations in the enclosure showed that barasingha avoided forest tracts during the growing season. The low number of beds caused by 7 barasingha during a period of approximately 3 months further indicates the repeated use of single beds. Some of them must have been frequented 30 or more times.

4. Migration between Ranges

Barasingha were relatively sedentary within

their seasonal ranges. Movements rarely exceeded 1-2 kilometres in a 24 hour period. A different type of movement, however, occurred between the two composite seasonal ranges: barasingha moved to their growing season range after the onset of the monsoon in June and July and returned to the cool- and dry season range in November and December. Adult stages were the first to leave their seasonal ranges. Their movements away from the southern part coincided with the onset of the first monsoon rains. In 1972 two individually known adult stags were last seen at the northern edge of the Kanha Meadow on June 22, 2 days after the onset of heavy monsoon rains. On June 24 they were recorded in the Sonph Meadow, 7 airline kilometres north of that location. More stags followed before the first females were recorded in Sonph on July 23. A relatively coherent female-young group of 33 individuals even remained around the Kanha Meadow until July 27. The month of July was thus marked by a discrete dispersion of sexes among the two ranges. In this transitional stage, up to 16 adult males temporarily aggregated in one group in the northern part,

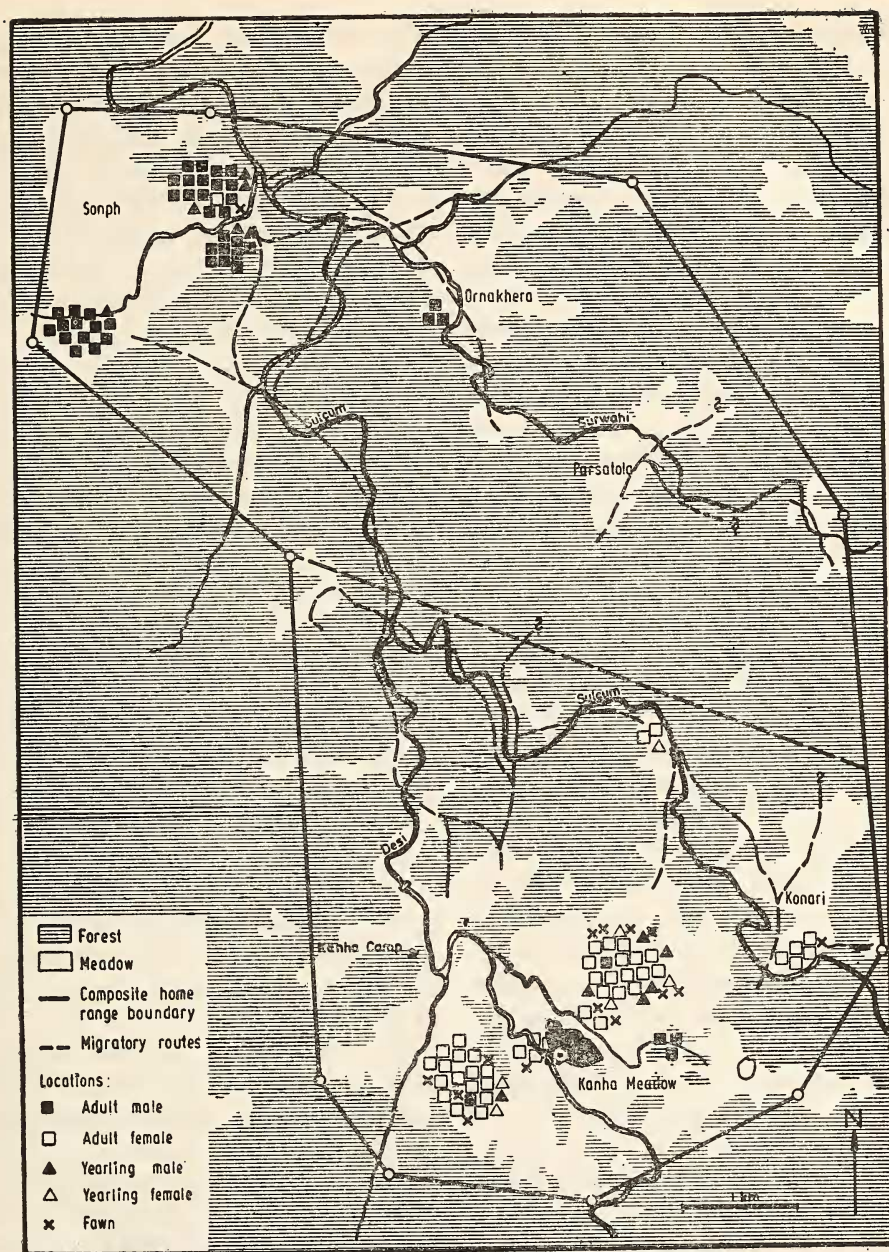


Fig. 11. Discrete dispersion of sexes in the composite home range during the period of monsoon migrations. From classifications July 1972. Travelling routes inferred from direct observations and tracks.

whereas the majority of the females and young animals were still in the southern part of the composite home range (Figs. 5 and 11). Females and young animals then left the southern part at the end of July, roughly one month after the first males were recorded in the northern part. Adult males were again the first appearing on the rutting grounds of the Kanha Meadow in early December.

Fig. 11 shows migrational routes between ranges inferred from direct observations and tracks. They indicate that barasingha head directly towards meadows of the other seasonal range. River courses connecting the meadows from preferred travelling routes. Barasingha moving between ranges appeared to be merely in small groups or solitary.

Migrations between seasonal ranges in deer were suspected to be adaptations to satisfy nutritional requirements. Such movement are well documented for elk (*Cervus canadensis*) (Schwarz & Mitchell 1945; Altman 1952; Picton 1960; Dalke 1965; Knight 1970; and Craighead *et al.*, 1973) and moose (*Alces alces*) (Edwards & Ritcey 1956; Phillips *et al.*, 1973; and others). These species often have distinctly different ranges during summer and winter. Decreased snow depths permit them to leave their spatially limited winter ranges in spring. Wanderings can be understood as adaptation to seasonally different food conditions in different areas.

The adaptations of the barasingha in Central India may altogether be paralleled with the above findings:

Whereas it is snow depth that effects spatial limitation during winter in colder climates, it is the scarcity of water that effects it in barasingha during the cool—and dry season in Central India. However, water also has a direct influence on the structure of the grass flora, in so far as the grass cover is more eutro-

phic where water conditions are good. The influence of water and food on the seasonal migrations, therefore, remain indistinguishable.

Though adaptation to seasonally different water—and food conditions may sufficiently explain migrations, another question remains: What is the mechanism that permits the barasingha to head for distant meadows by direct movements? This question shall be dealt with in the next section.

5. Traditions

Deer are known to have a strong tendency to return to their seasonal ranges over the years, as has been shown by Dasman & Taber (1956), Robinette (1966), Geist (1966), Knight (1970), Craighead *et al.* (1972) and Verme (1973). Ueckermann (1968) mentioned that in old fallow deer areas, the same rutting grounds were frequented over 50 and more years.

A comparison with Schaller's (1967) observations indicates that the composite cool—and dry season range of the barasingha in Kanha remained located in the same area around the Kanha Meadow. Previous reports had mentioned the importance of this meadow with respect to the barasingha during the dry season (Brander 1923). The recurring use of the same area alone, however, does not necessarily imply traditions.

Yet the following observations undoubtedly point to homing tendency. In both the rutting periods that were witnessed during this study, barasingha were found to restrict their rutting activity to the same limited areas of the Kanha Meadow (Fig. 4). No obvious ecological factors appeared to be responsible for the delineation of these areas. Even more conspicuous was the use of the same wallows in both the years, in spite of the abundance of muddy places in—and around the rutting ground. Barasingha

were already shown to be loyal to their wallows by Schaller (1967). Although the number of wallows had increased from 4 in 1964/65 to 9 in 1972, it was quite striking to see that at least one of the wallows of 1964/65 was still frequented during the rut of 1972 and 1973 (compare plate 11 in Schaller, 1967). This suggests an existence of traditional bonds at least to the rutting ground. The loyalty of the barasingha to its rutting ground in the Kanha Meadow may have evolved as a consequence of the localized abundance of water and green forage in this area during the cool—and dry season. The barasingha moreover were under legal protection in this area, ever since protection measures were introduced in 1935. Since there are traditional bonds to the rutting ground, the movements to these areas may also be directed by tradition.

There is little information about the loyalty of the population to its growing season range. In chapter III-3 I mentioned, that barasingha started repopulating the Sonph Meadow only after its village was translocated in 1969. Schaller (1967) showed that even prior to this the majority of the barasingha used to move away from the vicinity of the Kanha Meadow during monsoon. As the barasingha's activity is largely confined to the open grassland of the sal area during the growing season, it may be assumed that the northern meadows were always frequented. Yet, due to man—and cattle activities until 1969, barasingha were probably forced to disperse into marginal land. The dispersion of the population during the growing season, therefore, was probably wider before 1969 than during the period of this study. Congregations in the northern part of the composite home range, as they were found in 1972, obviously did not occur. It is likely, however, that this had negative influences on the coherence and the population dynamics of the

herd, even more so, because the fawning period comes in that season.

IV HABITAT UTILIZATION

We have come to the conclusion that the barasingha's activity is largely confined to open grassland throughout the seasons. Grazing grounds during the cool—and dry seasons are distinguished by the presence of water and unburnt grassland. In the growing season range concentrated around open rivulet zones. This prompts the question as to what the food habits of the barasingha are.

The following section is an attempt to answer this question. Then the utilization patterns of possible competitors among the herbivores of the park will be considered. On the basis of habitat preference and food habits I shall then make a few remarks on the evolution of the barasingha.

1. Seasonal Food Habits

I suspected that almost every grass species would be eaten by barasingha on certain occasions. However, the dominance of a species and its distribution pattern in a certain locality has a great deal to do with its preference rating. The quantity fed from a certain species may therefore have only local application. Standardized observations in a heterogeneous grassland habitat are almost impossible. Smith (1952) has reported on this central problem of food habit studies. Therefore I will only describe more qualitative differences of barasingha-forage in different seasons:

Table 3 shows an appraisal of those 26 grass species which were found to be the most common in the Kanha Meadow (see chapter VII).

Indications are based on a large number of unsystematic observations. Identifications of grazed plants were made on the spot, immediately after the grazing animal(s) had been

TABLE 3
SEASONAL BARASINGHA DIET OF COMMON GRASSES IN KANHA N.P.

Species	cool- and dry season 15.12.-31.5.	early monsoon and growing season 1.6.-14.12.
<i>Apluda mutica</i>	+	++
<i>Arthraxon quartinianus</i>	-	+
<i>Bothriochloa odorata</i>	+++	+++
<i>Chionachne koenigii</i>	++ (g)	?
<i>Diandrochloa japonica</i>	+	+
<i>Digitaria stricta</i>	+	+
<i>Dimeria connivens</i>	+	+
<i>Eragrostiella bifaria</i>	-	-
<i>Eragrostis unioloides</i>	-	+
<i>Eulalia trispicata</i>	++	++
<i>Heteropogon contortus</i>	++	++
<i>Ischaemum indicum</i>	-	+
<i>Ischaemum rugosum</i>	-	+
<i>Iseilema prostratum</i>	+	+++
<i>Mnesithea laevis</i>	+	++
<i>Narenga porphyrocoma</i>	+	+
<i>Panicum austroasiaticum</i>	-	+
<i>Phragmites karka</i>	+	++
<i>Pseudopogonatherum contortum</i>	+	+
<i>Saccharum spontaneum</i>	+++	+
<i>Schizachyrium brevifolium</i>	+	?
<i>Setaria glauca</i>	++	+
<i>Sorghum halepense</i>	+	++
<i>Themeda quadrivalvis</i>	+	+++
<i>Themeda triandra</i>	++ (g)	+++
<i>Vetiveria zizanioides</i>	++	+
intake: high	+++	medium ++
very low or none	-	(g): fed upon only when green
		low +
		underlined signs: fed upon regularly

watched through binoculars. Identification of grasses was critical during their growing period. Grazed specimens were thus marked with aluminium tags and identified later on, when flowering. When dry, however, all 26 grass species concerned may be identified.

(1) Cool-and dry season (15th December—31st May):

Most conspicuous forage was *Saccharum spontaneum*. Monotypic, dense stands along water courses were regularly and extensively grazed upon

throughout these seasons. Riverine *Saccharum spontaneum* was by far the most important barasingha forage also in forest tracts (Fig. 12). *Bothriochloa odorata* formed the bulk of the barasingha's diet in dry open- and dry shady locations, but green leaves of *Themeda triandra* were also heavily grazed upon. Except for the coarsest, which were only fed when green, grasses were eaten whether green or dry. Where available, however, green plants or parts of them were favoured.

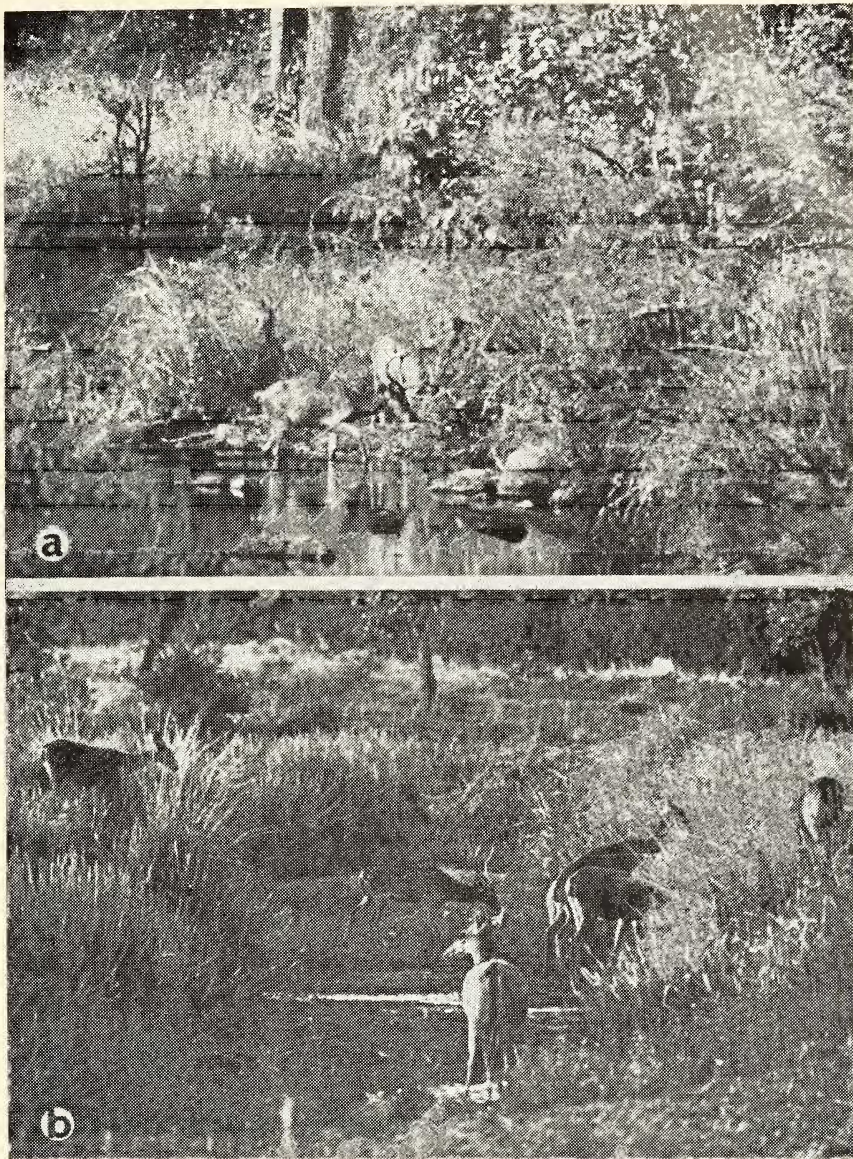


Fig. 12. (a) Group of barasingha stags feeding upon stands of *Saccharum spontaneum* in a stream bed north of the Kanha Meadow. June 1972 before the onset of monsoon rains. (b) Barasingha and chital collecting on riverine *Saccharum spontaneum* in the Kanha Meadow during the dry season.



Fig. 18. Pole used to measure grass height. The lowest figure visible on the board from a horizontal distance of 10 m was taken as grass height. Note: Difference of grass height in *Bothriochloa odorata* association at boundary where the fire was put out 11 months ago. Photo taken in November.

(2) Early monsoon-and growing seasons (1st June—14th December):

A large variety of new sprouts was fed upon during the early monsoon season. Preferences for certain species seemed less conspicuous then during the cool-and dry seasons. Though, barasingha subsisted often on locally limited "facies" of *Themeda triandra* and *T. quadrivalvis*. *Bothriochloa odorata* was still important food. *Saccharum spontaneum*, much in contrast to the dry season, was scarcely eaten. During the flowering time in October and November, leafy perennials like *Sorghum halepense* and *Phragmites karka* were heavily grazed upon. Inflorescences of *Themeda triandra*, *Sorghum nitidum*, *Bothriochloa odorata* and others supplied further forage.

The diet included the coarsest of species such as *Narenga porphyrocoma*. Even barbed species such as *Chionachne koenigii* were fed upon occasionally. Meagre annuals like *Dimeria connivens* were regularly taken, even when dry. But intensive grazing activity was generally confined to stout perennials.

Schaller (1967) has already reported an almost exclusive grass diet. He recorded merely six woody plant species fed upon by barasingha. Throughout this study much attention was paid to forage plant identification. The observations of barasingha eating browse were so few that they may be mentioned here separately. Of the six woody plants listed by Schaller, barasingha were seen feeding during this study upon: *Ziziphus jujuba* and *Moghania congesta* at one instance each, by one animal, and *Embelia tseriamcottam*⁸ twice, by one

animal at each instance. The other three species were not recorded as barasingha forage during this study, in spite of their abundance. In one instance, however, two barasingha were found eating the fruit of *Cordia myxa*. Even in forested areas, where browse was in lavish supply, barasingha concentrated on the grasses of the undergrowth and of small openings; but particularly on the stands of coarse grasses bordering river courses. Bamboos (*Dendrocalamus strictus*), although gramineous and locally abundant, were chiefly avoided. *Cyperacea* species were occasionally taken, but did not make up a conspicuous part of the diet at anyone season. On several occasions during the dry season, however, barasingha were seen submerged in the water of perennial rivulets and pools. Standing in water up to their belly, they fed from water weeds (*Najas* sp., *Vallisneria* sp., and others) below the surface. Much in contrast to the other ungulates of the park, natural and artificial saltlicks were practically disregarded. These observations demonstrate an almost complete avoidance of browse at anyone season. Barasingha are thus rather unique in their diet. They subsist on grasses to such an extent, that it is difficult to compare these findings with the food habits of any other of the deer species.

2. Interspecific Competition

Apart from the barasingha the meadows of the intensive study area are regularly frequented by the herbivores chital, sambar and blackbuck, of which the latter however is restricted to the dry open ground of the Kanha Meadow. Gaur come down from the hills to the sal area only during the dry season, yet here their activity is largely confined to the forest and

⁸ *Embelia tseriamcottam* is a relatively rare shrub, which is heavily browsed upon by all ungulates in

the park, including the graminivorous black buck (*Antelope cervicapra*).

riverbeds. Muntjac and fourhorned antelope hardly ever leave the forests of these areas. Nilgai are rare and occur only sporadically in the northern part of the intensive study area. As in the rest of the park, the chital is by far the most numerous ungulate. Approximately 4000 chital lived in the intensive study area in 1972.

Particularly during the cool- and dry season barasingha and chital were often found to form mixed herds when grazing. The grass species fed upon by barasingha were, however, favoured also by chital. This was particularly true for *Bothriochloa odorata*, *Themeda triandra* and *Saccharum spontaneum*. During the dry season mixed barasingha-chital herds concentrated regularly on monotypic stands of riverine *Saccharum spontaneum*. These species, but particularly *Saccharum spontaneum*, subsequently showed severe signs of grazing impact at the end of the dry season. Heavy grazing impact was, however, largely confined to the area of the Kanha Meadow. This implied that competitive exploitation may occur between barasingha and chital.

In order to collect information on the utilization patterns of the major grassland users in the intensive study area, the distribution patterns of chital-, barasingha- and sambar fecal pellets were checked. A comparison of utilization patterns by recording pellet frequencies was preferred to direct observation of deer, because results remain unaffected by different

time-space patterns of different species.

a) *Deer Pellet Count*

A pellet count was originally designed to give information on the seasonal dispersion of chital, barasingha and sambar among the intensive study area meadows.⁹ Yet, the sampling intensity required to obtain a representative sample of a given area depends upon the density and distribution of pellet groups. Grieb (1958) gives a formula to determine the required sampling intensity. A preliminary survey, however revealed that high variance among samples would have required a very large number of plots to show seasonal and regional differences.

A modified pellet count technique was thus used to answer a slightly different kind of question: Is the amount of barasingha pellets in a certain locality correlated with the number of chital and/or sambar pellets? In other words: If we do not distinguish between areas, are those plots with relatively high, respectively low rates of barasingha pellets, the same as those that have high, respectively low rates of pellets of other species, or not?

We may interpret the areas with high pellet frequencies to be those of heavy use. Thus, correlation of pellet frequencies from different species will give indications on common and/or discrete utilization patterns of these sympatric species. Seasonal aspects enable distinguishing between pellets that accumulate during the dry season and during the rest of one year.

⁹ Many attempts have been made to estimate the relative and actual number of deer of their days of use in a given area by counting fecal pellet-groups. Neff (1968) gives a review of the various methods used and their suitability under different conditions. Practically all methods use some stratified random distribution of sample plots. Among all the problems that arise if an estimation of the actual number of deer is to be computed, the figur-

ing of daily defecation rates is one of the most difficult. Defecation rates are subject to seasonal and regional changes. Sampling accuracy may be influenced by different deterioration rates under various cover conditions, e.g. forest vis-a-vis meadow. Rainfall can also cause the disappearance of pellet groups (Wallmo *et al.* 1962). Interpretational difficulties as in the case of peripheral or scattered groups in the sample plots may cause further bias.

TABLE 4

MEAN FECAL PELLET FREQUENCIES PER 50 SQUARE-METRE PLOT, FROM 84 PLOTS IN THE INTENSIVE STUDY AREA MEADOWS

Fecal pellet type	Initial count	March 14 to July 8	rest of 1 year	Total (1 year)
Chital	709.4	133.9	573.4	707.3
Barasingha	74.0	18.0	87.5	105.5
Sambar	46.9	6.7	23.5	30.2
Total	830.3	158.6	684.4	843.0

(1) Sampling:

A total of 84 plots were distributed in the intensive study area meadows. Plot sites were located according to a stratified random design and permanently marked with wooden pegs. Plots were 50 sq metres and circular. High pellet densities impeded the identification of pellet groups. Therefore single pellets were counted in divergence to other methods described. This way the problem of interpretation of peripheral or scattered groups was excluded.

The first count was carried out from March 12-16, 1972. Consecutive counts were carried out on July 5-12, 1972 and March 8-13, 1973. Each time pellets were classified, counted and removed from the plot. Due to extensive fires that destroyed the grass cover in most of the meadows before the first count, the pellets could be collected easily. The second count, which took place before the next growing period, also went smoothly. For the last count the grass on the plots had to be cut prior to the count.

—Thus, the first count comprised all pellets from before the count period, the second count those of the four months of the past dry season, and the third count those pellets that accumulated from July to the following February.

(2) Durability of pellets:

Whereas pellets in the forest may be lost by concealment in litter as well as other reasons within less than one year's time, pellets in the meadows lasted for at least a year. The total amount of pellets from the two count periods (1 year) is comparable to the total amount from the initial count (Tab. 4). Considering the general increase of deer and accordingly, pellet frequencies, we may assume that the pellets collected in the initial count date back from a period of a little more than

one year. Generally pellets dry up quickly and remain unaffected until the next monsoon. However, they did not weather the second monsoon. Those pellets dropped during a period of heavy rain may get lost within the same monsoon season. Occasionally pellets were lost due to termite attack. Nevertheless, neither type of loss seems to affect the results of semiannual or annual counts seriously.

(3) Species identification of pellets:

The year before the first count was carried out, pellets of observed animals of the three species were collected and compared. The diameter of chital pellets vary from 6.5-9.0 mm, whereas barasingha- and sambar pellets are always wider. Barasingha pellets are cylindrical in contrast to the pileate and wider sambar pellets. Chital- and sambar pellets are usually dark brown to black when dry, whereas barasingha pellets are light brown. The shape of pellets were fairly constant, except during the monsoon when deformed pellets also occurred. Soil-containing pellets occur in chital and sambar only, as barasingha do not frequent natural or established salt licks. Because of the barasingha's exclusive grass diet, fragments of browse in pellets point to either chital or sambar. Occasionally pellets had to be disregarded due to the difficulties involved in identifying them.

b) *Correlation of Species Pellet Frequencies*

Spearman Rank Correlation tests revealed that barasingha and chital pellets commonly occur together. Rank correlation co-efficients (Tab. 5) show a significant positive correla-

TABLE 5

CORRELATION OF BARASINGHA PELLET FREQUENCIES WITH PELLET FREQUENCIES OF CHITAL AND SAMBAR; FROM 84 PLOTS IN THE INTENSIVE STUDY AREA MEADOWS

SPEARMAN Rank Correlation Tests

Coefficients $|r_s| > 0.2151$ ($2\alpha = 0.05$; $n = 84$) are significantly different from 0. ($p < 0.05$).

Correlation of barasingha pellet frequencies with pellet frequencies of:	Dry season	All other seasons
Chital	$r_s = 0.4690$	$r_s = 0.2323$
Sambar	$r_s = -0.3300$	$r_s = 0.1810$

tion between the occurrence of barasingha and chital pellets for the dry season, but even the positive coefficient for the remaining period of the year has statistical significance. Yet, there is a significant negative correlation between the occurrence of barasingha and sambar pellets for the dry season. The occurrence of pellets of these two species during the rest of the year is positively correlated, though not significantly. The fact that the occurrence of barasingha and chital pellets are correlated suggests two things:

- (1) The dispersion of barasingha and chital among the intensive study area meadows tends to be proportional.
- (2) Within meadows the same areas are subject to heavy use by both species.

Sambar though appear to use the meadows of the intensive study area according to a different pattern.

These findings are supported by direct ob-

servations of deer. The dispersal of chital as well as barasingha seems to be governed by the availability of water during the dry season. Hence they congregate around the Kanha Meadow. As expected, barasingha pellets occurred only in the southern part of the intensive study area during the dry season. Chital pellets occurred in all the meadows, though they were in highest density in the south. During the rest of the year barasingha pellets occurred also in the northern part of the intensive study area, and chital pellets were in about equal density in both the parts.

On the other hand, sambar pellets were always more frequent in the northern meadows. This species seems not to be affected by water scarcity in these areas during the dry season. As shown in Tab. 4, the number of sambar pellets was low compared to the other species' pellets, particularly chital pellets. This points to insignificant use of the meadows. The park's sambar are predominantly browsers and enter the meadow only during the night. As mentioned before, sampling intensity was insufficient to give regional differences of statistical significance.

Common utilization of grassland by chital and barasingha does not mean a priori that the chital has the same utilization pattern as the barasingha. The chital has a wider range of food preferences; also browse plays an important role in the ecology of this species (Schaller 1967). But wherever chital pass over to meadows, the same grounds are also favoured by the barasingha. The overlap of the utilization patterns of these two species is promoted by the lack of interspecific avoidance (mixed herds). Various authors have reported an overlap in food habits of sympatric deer species. Krämer (1973) suspected competitive exploitation to be the only mechanism of competition in sympatric whitetailed deer (*Odo-*

coileus virginianus) and mule deer (*Odocoileus hemionus*) populations with densities below the maximum. Martinka (1968) and Kamps (1969) expected competition to occur between these species in the case of scarcity of certain forage plants in winter, when other forage is short.

This situation, however, is comparable to the food shortage in the Kanha Meadow after extensive burns have taken place (Chapter VII-4). The assumption, that competitive exploitation of certain grass species by chital and barasingha arises here during the cool- and dry season appears therefore to be consistent.

3. Evolutionary Aspect

The outstanding importance of eutrophic moist grasslands for the barasingha suggests that it is one of the most stenoecious among the deer. This is even more conspicuous in northern and north-eastern India, where the barasingha hardly ever enter the forest due to extensive grasslands and marshes which seem to cover all their requirements. Habitat selection to cover nutritional requirements may, however, be considered a phylogenetic adaptation that evolved in the corresponding habitat. Hence the question arises as to which was the area of differentiation of the species:

Except perhaps the more arid parts of the Thar desert, the natural vegetation of the Indian Subcontinent was essentially arboreal. Tropical grassland and marshes occurred only in riparian flats inundated by flood water of the Brahmaputra River and in the alluvial flood areas of the middle and lower Gangetic Plain. From the point of view of habitat preference, it seems therefore reasonable to as-

sume that the differentiation of the species took place in its present northern and north-eastern range, and was dominated by the alluvial flood plains deposited after the tertiary uplift of the Himalaya. The colonization of the archaean and densely forested peninsula would consequently have occurred during a later period.

Indeed, Mani (1974) in his comprehensive biogeography of India pointed out that the present-day mammalian fauna of the peninsula is largely constituted by intrusive elements of the tertiary humid tropical Indo-Chinese and Malayan subregions. The fauna that differentiated in these eastern "amphitheatres" is unlike the Peninsular faunas composed of phylogenetically much younger groups, such as the cervids. They are characterized by a high degree of plasticity, and often diversified to local subspecies after the inflow into the Peninsula in the Pleistocene times. This may also be valid for the diversification into subspecies of the barasingha. Kurup (1974) showed that the mammalian faunal flow in the Post Tertiaries from the Indo-Chinese sub-region entered India through Assam and bifurcated, one branch spreading to the Peninsular India and the other across the Sub-Himalayan belt further west. The barasingha's distribution last century had similar pattern (see Fig. 1).

This would mean, that the differentiation of the barasingha occurred in Assam or even further in the east of the Indo-Chinese sub-region. A remnant of speciation, the closely related brow antlered deer (*C. eldi*)¹⁰, was in present times still being found in these areas. Yet the details of the evolutionary processes that happened here are unknown; all the more,

¹⁰ Although little is known on the ecology of *C. eldi*, in Manipur it is an inhabitant of floating swamps with tall reeds (Ranjitsinh, personal comm.)

which may suggest similar habitat requirements as in barasingha.

there is a lack of paleontological evidence on the species level. Still there is little doubt that the peninsular occurrence of barasingha dates back to a relatively recent, i.e. post tertiary, colonization.

V GROUP CHARACTERISTICS

Deer were generally assumed to have reached firm group sociality. This idea apparently originated from the descriptions given by Darling (1937) for red deer in Scotland. More recent studies however revealed, that grouping is largely dependant upon environment and changes in physiological functions.

Schaller (1967) stated that barasingha groups tend to break up and reassemble in different groups. It was observed at the beginning of this study, that barasingha groups occasionally changed their composition several times a day. Individuals of a group often scattered while grazing, which incidentally led to the breakup of the group. Single animals or small parties later met with different animals

on grazing grounds or shady resting locations to form again larger groups.

Frequent changes of group compositions were particularly conspicuous during the dry season. This was the period, when the daily movement pattern was lively and strongly influenced by the avialability of food, water and shade (chapter III-2).

The size and composition of barasingha groups were analyzed for seasonal changes.

An analysis for changes of vegetational type was done for the cool- and dry seasons, when barasingha were relatively mobile and also frequented sal forest areas.

Characteristics of barasingha groups were based on 689 records of groups totalling 5200 observations of individual barasingha. 613 groups were classified as to sex and age. Three types of groups were distinguished:

All male groups, female- young groups and mixed groups. Single animals were considered as groups consisting of one animal. The above terms were defined as follows:

— All male group: Any combination of

TABLE 6
MONTHLY SIZE OF BARASINGHA GROUP TYPES. POOLED CLASSIFICATIONS 1971-73

	Total sample		All groups		All male groups		Female-young groups		Mixed groups	
	No. groups	No. baras.	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Jan	50	468	9.4	1-70	1.3	1- 3	3.1	1- 6	12.0	3-70
Feb	62	628	10.1	1-63	1.9	1- 5	3.4	1- 9	18.0	2-63
Mar	103	1047	10.2	1-61	3.9	1- 8	6.0	1-28	13.7	2-61
Apr	8	72	9.0	1-27	—	—	—	—	—	—
May	85	666	7.8	1-28	4.3	1- 8	6.0	1-15	10.1	3-23
Jun	83	725	8.7	1-36	2.7	1-10	6.2	1-21	12.5	4-38
Jul	31	405	13.1	1-33	3.3	3- 4	5.5	1-11	17.1	10-33
Aug	40	147	3.7	1-21	2.4	1- 7	2.4	1-11	7.8	5-21
Sep	80	370	4.6	1-19	1.4	1- 3	1.6	1- 3	6.3	2-19
Oct	48	218	4.5	1-19	1.0	1- 0	1.8	1- 4	6.2	2-19
Nov	36	180	5.0	1-15	1.5	1- 2	2.5	1- 5	6.3	2-11
Dec	63	274	4.3	1-32	1.2	1- 3	2.8	1- 7	6.9	2-30
Whole year	689	5200	7.5	1-70	2.3	1-10	4.2	1-28	10.3	2-70

males older than one year.

- Female-young group: Any combination of females, yearlings and fawns, except all yearling male groups. Solitary females with fawns at foot were classed as single females.
- Mixed group: Any combination of adult males with animals from other classes, except yearling males.

1. Seasonal Grouping Pattern

The mean group size for the whole study period was 7.5 animals/group. This is in accordance with the mean of the mean monthly group sizes of 7.5 animals/group.

Tab. 6 shows the monthly size of the three group types, and Fig. 13 the segregation of sexes. The April sample was too small to give representative values on the group type level.

All male groups were constantly smaller than female-young groups. Highest mean group sizes were attained by mixed groups. The peak of rutting activity in January was marked by a maximum of animals conforming to mixed breeding herds. Temporally limited peak aggregations of up to 70 animals occurred on the Kanha Meadow during the late rut consolidation of breeding herds, stag groups and female-young groups. The months thereafter, from February onwards, brought a progressive segregation of barasingha into groups of their own sex, accordingly with an increase of the mean size of the all male and the female-young groups. Segregation between sexes reached a peak during the driest period of the year in May. The maximum for the year, of females living in female-young groups was reached in this period. After the onset of the monsoon, barasingha gathered on large meadows new sprouts of which brought about the highest mean group size (without regard to composition) of 13.1 animals. The situation

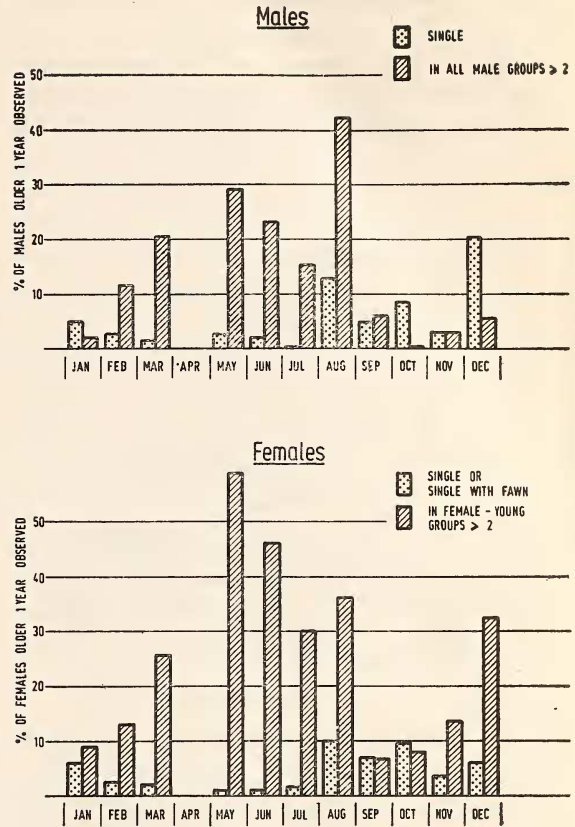


Fig. 13. Monthly segregation of barasingha into monosexual groups. From classifications 1971-73.

drastically changed by the beginning of the fawning period in August. Early monsoon aggregations had split into small groups and a high percentage of singles. Segregation of sexes reached the second peak of the year. Single females were at maximum, indicating separation for parturition. In the months thereafter, mean group sizes and segregation of sexes were at maximum. This situation remain relatively stable until November. The onset of rutting behaviour in December was again marked by segregation of sexes and the highest percentage for the year of single males.

Single individuals were observed throughout the year. The relationship between the percentage of single animals and the mean group sizes, without regard to composition, was used to analyse grouping mechanisms (Fig. 14): In-

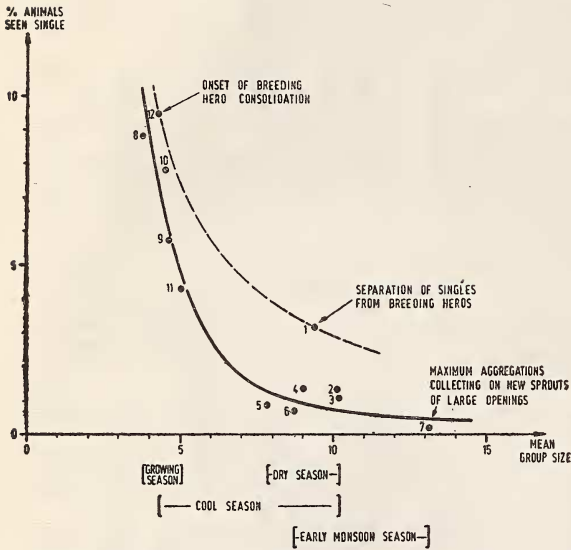


Fig. 14. Seasonal relationship between mean group size and percentage of singles. From classifications 1971-73. Note: Solitary females with fawn were classed as single animals. Numbers along the curve indicate months. Dotted line: hypothetical run for grouping during the rut.

creasing mean group size effects an exponential decrease of the probability to see single animals. Such a curve was to be expected. Yet, the positions within the coordinates and the flexure of the curve must be considered to be typical for this particular population. A sharply bent curve could signify that with increasing mean group size, single animals get readily absorbed in groups; a more linear curve would imply many animals remaining single or even actively avoiding association with other individuals. Deviation from the general relationship, finally, may be interpreted as being caus-

ed by factors different from those responsible for the general relationship. The dotted line in Fig. 14 indicates a more linear run of the curve based on the deviation of the January value. It shows the hypothetical development of grouping during the rut: December is characterized by a low mean group size of 4.3 and the highest percentage for the year of single animals. This marks the beginning of breeding herd formations. 77% of the singles are adult stags appearing on the rutting ground. By January breeding herds account for a higher mean group size of 9.4 animals/group. The percentage of animals seen single has decreased accordingly, yet remains relatively high. The deviation of the January value is caused to equal degrees by solitary low ranking stags not being tolerated in breeding herds, and solitary hinds with fawn avoiding association with rutting stags.

These singles however join the post rut aggregations in February and March. The values for these months subsequently fit again into the general relationship.

We may presume thus, that during the rut grouping is determined by different factors. The deviation may be attributed to social interactions, or more precisely—separation or exclusion of certain animal classes from the rutting procedure during the peak of the rut. I will later show that lactating females avoid association with rutting stags.

The fitting into the curve of the other monthly values, on the other hand, points to absence of this social mechanism. The conjecture is prompted that grouping is determined by environmental factors during the rest of the year.

2. Grouping in Relation to Vegetational Type

Changes of group size and composition coincided with changes in vegetational type during the cool- and dry season. The occasions where

barasingha were observed within the forest areas were relatively rare. This could partially be ascribed to better visibility on open ground. Yet it appeared also that forest tracts were merely crossed to reach feeding grounds and watering places in other openings, which contributed further to the low chance of observing barasingha within the forest. Those few cases, however, where barasingha groups were located in the interior of the forest suggested, that these groups had a composition that differed as to sex and age from the usual pattern. Tab. 7 shows that groups in the forest had a higher proportion of adult males and adult nonlactating hinds, whereas hinds with fawns and yearlings were less represented. A lower percentage of female-young groups was observed in the forest, whereas the other group types were represented with higher values.

This indicates that the preference for one of the two vegetational types is not simply related to sex, but rather to age. Both sexes

may leave the open areas. Females with fawns at foot and yearlings, however, tend to conform to groups remaining on open ground.

Absence of cover on open ground lowers the risk of predation by tiger. It is likely that this yields the motive for avoidance of timbered areas by female-young groups.

The mean group size was comparatively higher at 7.8 animals/group in the open type than the mean group size of 5.8 animals/group observed in the forest. The sample of barasingha seen in the forest was however too small to give this difference statistical significance. Knight (1970) found maximum group sizes of elk (*Cervus canadensis*) cow-calf groups on open grass types, suggesting similar mechanisms. According to Halder (1973) the social organisation of a species represents a phylogenetic adaptation to various factors of the habitat in which the respective species customarily lives.

TABLE 7

SEX AND AGE DISTRIBUTION AND GROUP TYPES OF BARASINGHA IN TWO VEGETATIONAL TYPES (Pooled classifications cool- plus dry season 1971-73). The distributions of sex and age classes differ significantly between open areas resp. forested areas ($\chi^2 = 14.00$; d.f. = 3; $p < 0.01$)

Observed in	Animal classes					Group types			
	Adult males	Adult females	Lactat. females	Yearling ♂ + ♀	Animals in sample	All male Groups	Female young groups	Mixed groups	Groups in sample
					1788				280
Open areas	31.8%	21.7%	22.6%	23.9%	100%	20.4%	35.7%	43.9%	100%
					146				30
Forest areas	38.3%	30.1%	18.5%	13.0%	100%	30.0%	20.0%	50.0%	100%
Difference of % in forest	+6.5%	+8.4%	-4.1%	-10.9%	—	+9.6%	-15.7%	+6.1%	—

3. Group Constancy

The frequent changes of group size and composition and the adaptation to different habitat types lead me to conclude, that barasingha groups have no real constancy in the social sense. This was further supported by the repeated observation of individually known barasingha in groups of different composition or as single individuals. Although a number of stags were recorded throughout the cool- and dry seasons, none was seen twice within a group of the same composition. Even breeding groups were subject to constant exchange of individuals.

The highest degree of stability in this respect was noted during monsoon when food was abundant and daily movements at minimum; 33 females and young animals that remained in the Kanha Meadow during the early monsoon season 1972 were repeatedly seen in one group but also in various sub-groups over a period of 16 days. Congregation in one group, however, appeared to be accidental and caused by coincident grazing ground, rather than by social factors. Two adult stags were known to have moved together to the northern range between June 22 and 24, 1972, where they were seen associated over a period of 28 days. Yet no larger group was known to have remained intact over such a period of time. The only stable relationship between two animals seemed to occur between a hind and her fawn, until the latter was approximately 1 year old.

Related deer species of the temperate and cold climates were found to have analogous grouping patterns: Lowe (1966) reported, that marked red deer (*Cervus elaphus*) on Rhum in Scotland may sometimes be found with one group, sometimes with another. Schloeth (1961) doubted, that red deer in the Swiss National Park would form lasting associations of

any size. American elk (*Cervus canadensis*) were found to form no strong or enduring association by Craighead *et al.* (1973), Moran (1973), Knight (1970) and others. The latter proposed, that groups which tend to break up and reassemble with different combinations should more properly be called "aggregations." He further stated, that: "such aggregations owe their existence to environmental factors rather than social responses ... which however does not preclude the existence of a wide range of social responses including dominance hierarchy."

According to this, grouping in barasingha is most probably a function of environment, except perhaps for the deviation in grouping habits that was found during the rutting period.

VI POPULATION STRUCTURE AND REGULATION

1. Population Size

A population living in a habitat with dense cover and undulating terrain may not be accurately censused to the last individual by any known method. Whereas the visibility in the Kanha Meadow is sufficient to give very accurate census results of the animals staying in the meadow at the time of censusing, forest areas cannot be scanned completely. Methods of estimation such as the "Lincoln Index" have been found to give unsatisfactory results due to different probability of observation among sex and age classes in different habitat types (Krämer 1967). Andersen (1961, 1962) checked many of the traditional methods and concluded that they normally resulted in under- rather than over estimates of the real population. The census figures presented here must therefore be taken as minimum, where there was no mean for adjustments.

a) *Method of Count*

Total census were carried out on June 10, 1971; June 27, 1972 and March 26, 1973. The selection of dates for the censuses coincided with periods when a maximum number of barasingha congregated on the Kanha Meadow, either due to grazing from green grass shoots that sprouted after the first monsoon rains in June, or due to the forming of large herds at the end of the rutting period in March. In other seasons the population is more dispersed and less visible.

Censuses were carried out from a vehicle between 0600 and 0800 hours and repeated at 1600 to 1800 hours on two consecutive days. The Kanha Meadow was covered first, leaving more isolated herds for later. A separate census was done by the Forest Department in 1971. The censuses of 1972 and 1973 were carried out in cooperation with the Forest Department Staff. In order to avoid double counting and to receive reliable information on the sex and age structure, all counting and classifying was done by the same team consisting of myself and the Divisional Forest Officer. Patrolling Forest Staff were sent out before the counting period to search all the areas in the basin of the Sulcum River. Sightings by the Forest Staff were confirmed after covering the Kanha Meadow.

The number of barasingha staying in the enclosure each year, namely 5 in June 1971, 7 in June 1972 and 8 in March 1973 were included in the census figures.

b) *Census Results* (Tab. 8).

The repetition of counts on each occasion showed that the method gave consistent results as to the number of females, yearlings and fawns.

The number of yearlings probably has the highest accuracy. Yearling classes are the most easy to locate and count due to their tendency

to stay in the open areas (Tab. 7). The number of yearlings was moreover confirmed by separate counts. These were in accordance with the census results, except for the yearling male class in 1973. 11 yearling males were counted on January 27, 1973 in one herd and on February 4, 1973 in two herds instead of the 8 yearling males tallied during the census. Although I cannot exclude that the 3 missing yearling males had died between February 4, 1973 and the census of March 26, 1973, it is more likely that they were not included in the census.

From the known number of yearlings, however, conclusions can be made on the minimum number of fawns that must have been living during the census of the previous year: 12 yearlings in 1972 and 21 in 1973, indicate that in 1971 at least 12 fawns and in 1972 at least 21 fawns were present.

A similar conclusion can be made for the determination of the adult females and males: Due to mortality, the number of adults, in one sex should be less than the sum of adults and yearlings of the same sex in the previous year. If the census yields a greater number, we may conclude that the number of adults had been underestimated in the previous year. This, however, assumes that the number of yearlings was accurate. In this way, 51 counted adult females in 1973 and the known number of 6 yearling females in 1972 suggest that at least 45 adult females were present at the time of census in 1972. An analogous conclusion can be made for the minimum number of 40 adult females in 1971. Thus, even though repetitions of censuses gave consistent results for female, yearling and fawn classes, the reconstructions suggest that in all repetitions of the counts in 1971 and 1972 a part of the female and fawn classes was missed entirely.

Further adjustments had to be made for the

TABLE 8

CENSUS RESULTS AND ESTIMATION OF REAL POPULATIONS 1971-73

		Adult Males	Yearl. Males	Adult Females	Yearl. Females	Fawns	Total
1971	Census June 10	20	6	29	5	11	71
	Concl. from 12 yearl. 1972					+ 1	
	Concl. from 45 ad. fem. 1972			+11			
	Minimum pop. June 1971	20	6	40	5	12	83
	Forest Dept. Census 6/1971						88
	Assumptive real pop. 6/1971	30	6	40	5	12	93
1972	Census June 27	22	6	36	6	13	83
	Reports June 27						(+ 13)
	Observed July 2	+3					
	Concl. from 21 yearl. 1973					+ 8	
	Concl. from 51 ad. fem. 1973			+ 9			
	Minimum pop. June 1972	25	6	45	6	21	103
	Assumptive real pop. 6/1972	34	6	45	6	21	112
1973	Census March 26	27	8	51	10	22	118
	Observed February 4		+ 3				
	Minimum pop. March 1973	27	11	51	10	22	121
	Assumptive real pop. 3/1973	39	11	51	10	22	133

adult male class. Adult males often roam solitarily in forest areas, making this class the most difficult to comprehend from a census. Repetition of counts yielded fluctuating numbers of stags. Even maximum census figures were known not to include individually known stags that were seen again only after the census. The assumptive number of stags was thus computed from the census figures of adult sex ratio determined in Chapter VI-2. This yields the assumptive real population size and structure for the years 1971-73 shown in Table 8.

2. Sex Ratio

All of the censuses indicate a sex ratio of 1:1 among yearling classes, which points to parity among sexes at birth. 1:1 distribution among yearling sex classes is also indicated in

classifications of larger groups throughout the year.

The determination of sex ratio among adults is more difficult. Substantial parts of the adult population were known to have been missed in the censuses.

The monthly totals of classifications in the southern range resulted in a fluctuating sex ratio, indicating unequal probability of observation of adults in different seasons.

Considering only the months of February and March, when large herd forming occurs at the end of the rut and the entire population congregates in the immediate vicinity of the Kanha Meadow, a sex ratio of 75.4 adult males to 100 adult females, results which give the approximate real sex ratio. No major change of the sex ratios in young animals and

adults has thus occurred since 1964/65.

3. Age distribution and Antler development

Under the conditions in question an attempt of aging the adult class could only be made by judging the antler development of males.

The first indications of antlers appear in

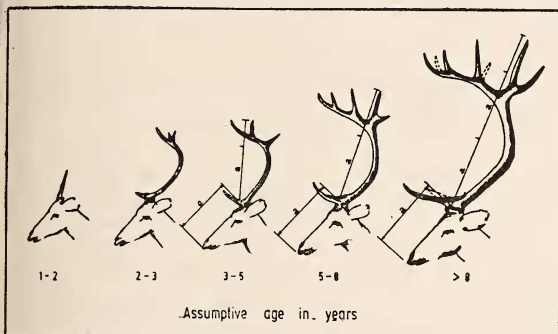


Fig. 15. Development of the barasingha antler. a—length of skull used to estimate antler length. Secondary tines dashed.

the fawn of 7 to 10 months, in the form of small bumps. Yearling stags carry spikes between approximately 7 and 20 cm length. The first set of adult antlers is acquired at the age of 2 years. Very old stags may carry

set back antlers with as few as 7 tines.

The age of stags older than 3 years is difficult to judge by antler development. The observation of both free and a few enclosed stags of known age permitted following the general development of antler stages. Data from red deer (Raesfeld 1964) supplied further information on the indication of the age (Fig. 15).

It is common knowledge that antler development is an unsatisfactory criterion for aging. Results using this criterion should thus be interpreted with care:

To class free ranging stags older than three years, I used the estimated length of the antler. This may give a somewhat more reliable indication of age than the number of antler tines. The distance from the pedicel to the most distant tip of the antler was compared with the distance between muzzle and pedicel to estimate the length of the antler (Fig. 15). This rate is indicated in Tab. 9 and allied with the assumptive age of stags.

The age structure in the male population was determined by observing and classifying stags at times during which all age classes were equally present in and around the Kanha Meadow, i.e. during and at the end of the

TABLE 9

ANTLER DEVELOPMENT AND DISTRIBUTION OF AGE CLASSES IN THE MALE POPULATION OF BARASINGHA, 1973

Age	0-1	1-2	2-3	3-5 (?)	5-8 (?)	> 8	Number in sample
Estimated length of antler in muzzle-pedicel lengths	—	(spike)	(brow tine short)	1-1½	1½-2	> 2	
Usual number of tines	—	(spike)	6-8	8-10	11-12	≥12	
Adult males classified Jan. - March 1973			42	75	97	47	261
Distribution according to assumptive real population 1973	18.0%	18.0%	10.3%	18.4%	23.8%	11.5%	100%

rutting period.

Tab. 9 gives the proportion of adult male classes derived from classifications of groups made from January till March 1973. It has been adapted according to the structure of the assumptive real population of 1973 shown in Tab. 8 to give the age distribution in the total male class. Since we may presume that the sex distribution among fawns is equal 1:1, the rate of fawns recorded was halved to obtain the rate of male fawns.

The distribution is marked by a high number of young animals. 36% of all males were less than 2 years old and 46.3% were less than 3 years of age. Only 11.5% were older than approximately 8 years. The high rate of yearling stags (18.0%) points to a massive increase in the reproductive success over the year 1971. The 1973 male population was remarkably young and characteristic of an increasing population.

a) *Changes of Age Structure in the Male Class*

A comparison with the conditions in 1964/65 is informative: Schaller (1967) determined the percentage of adult stags with antlers having 6-9, 10-11, 12 and 13-15 tines from 42 adult stags tallied in the standing population of barasingha in Kanha in 1964/65. Considering the mean from 1964 and 1965 of the rates of fawns and then yearling stags, a distribution of male classes was constructed. This is compared with the distribution among the same male classes of the 1973-population, determined from 90 adult stags tallied between January and March 1973 and the assumptive real population in 1973 (Fig. 16). Even though these antler classes may not be placed in year classes, the number of antler tines is correlated with age. The 1973 population of males shows a distinctive shift towards stag classes with fewer tines i.e. younger males. The majority of males had antlers numbering 6-9 tines. The male po-

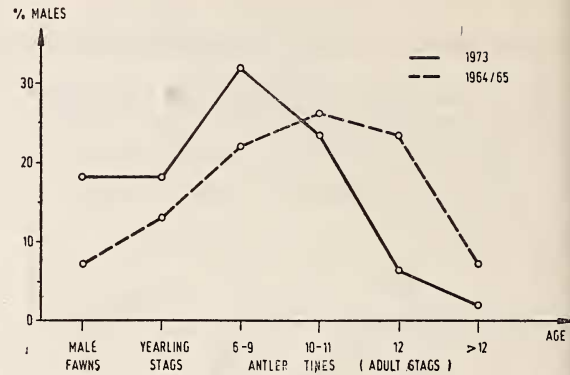


Fig. 16. Distribution of male classes in the barasingha populations of 1964-65 (adapted from Schaller 1967) and 1973 (the present study).

population of 1964/65 on the other hand was marked by a majority of stags having antlers with 10-11 tines and an extremely low rate of fawns. This low rate of fawns was due to a very low reproductive success in the year 1963 and 1964 and a decrease of the population from 82 animals in 1964 to 55 animals in 1965 where, however, all fawns recorded by Schaller in 1964 became yearlings in 1965. Thus, the yearling rate of the 1964/65 population became higher than the rate of fawns. The distribution of male classes in 1964/65 was characteristic of a decreasing population, whereas the 1973 population was younger and increasing.

4. Reproduction

a) *The Breeding Period*

Rutting activity occurred between mid December and mid March. Earliest bugling by stags was heard on November 29, latest on March 29. Bugling reached highest frequencies in the second half of January, coinciding with the peak of rutting activity. Although barasingha groups were roaming over larger areas and bugling was heard all over the Kanha Meadow and its vicinity, rutting activity in

groups was confined to limited areas within the Kanha Meadow in both the seasons 1971/72 and 1972/73 (see Fig. 4). A few large stags dominated the rutting area at the northern edge of the Kanha Meadow up until January 15, 1972, February 3, 1973 respectively. With the fading rutting activity of the largest stags, lower ranking stags appeared and rutting activity continued in large aggregations. Rutting of these stags continued until end of February around the Menar-Nala in the centre of the Kanha Meadow, and subsequently faded.

Schaller (1967) has already commented on the differences in the time of onset of the rut in different areas in northern India, compared to the park's population. The daily peaks of rutting activity occurred in the cool morning hours from 0630 to 0900 and between 1630 and 1830, coinciding with the peaks of grazing activity (see Fig. 6). During these hours, stags were repeatedly observed using the same 9 wallows within the rutting areas. Several copulations were witnessed in these areas between December 29 and January 29. Rutting stags seemed not to retain constant harems but confined their activity to estrus hinds. It was common to have several other stags within a breeding herd who challenged rutting stags around the periphery of the area.

Observations of rutting behaviour are in accordance with those described by Schaller (1967). Bugling, wallowing and foreplay appeared also to be in close accordance with that described for *Cervus canadensis* by Harper *et al.* (1967).

The time of peak rutting as well as the locality of the rutting areas obviously remained the same since 1964. However, the period during which rutting activity was recorded started earlier by 17 days and lasted more than a month longer. The duration of rutting activity thus seems to be related to the size

of the population as suggested by Schaller (1967). Indications from Forsyth (1889) who found a longer rutting period at times when barasingha were common in Central India, support this view.

The fact that the whole population's rutting activity was confined to the same area is not consistent with Schaller's (1967) suggestion that the maximum size of a coherent breeding herd could be around 60. However, Panwar (personal comm.) noted that some rutting activity occurred in the northern meadows during the rut of 1974/75, when the population reached approximately 150 individuals.

b) Gestation Period and Fawning

Asdell (1964) and Kenneth (1953) reported the barasingha to be a monoestrous deer with a gestation period of 240-250 days. The peak of rutting activity in the second half of January would thus suggest that the majority of fawns would be born in the second half of September.

A total of 8 new fawns were found during the study period. The earliest of them was recorded on August 6, suggesting conception in early December, and the latest on November 4, suggesting conception in early March. A pregnant hind that lived in the enclosure in 1971 delivered shortly before September 19, when the fawn was found. All of these new fawns hid in tall grass areas and were distinctly separated from other barasingha.

There was no evidence of twins during the study period. Indications that occasionally yearlings became pregnant were lacking; this possibility may not be excluded with certainty.

c) Reproductive Success

One characteristic of the barasingha population described by Schaller (1967) for the years 1964/65 was the extremely low reproductive success of the population, i.e. 15 fawns/100 hinds (adult + yearling) in 1964, and 16

fawns/100 hinds in 1965 respectively. This resulted in a rate of 7% fawns of the total population for both the years 1964 and 1965.

From the censuses carried out during this study, the fawning success was calculated as 26.7 fawns/100 hinds for 1971 respectively 41.2 for 1972 and 36.1 for 1973, concerning fawns that were born the year preceeding the respective census. The census thus included the fawns that had outlasted early fawn mortality. The data suggest a great increase in reproductive success since 1965. The fawning period of 1971 appears to have been particularly productive. Similar fawn crop was indicated by Schaller (1967) for the barasingha populations of West Kheri Forest and Kaziranga, i.e. 15-19% of the total population.

Considering other monoestrous deer, these rates suggest normal production (Knight, 1970; Craighead *et al.*, 1973; and others).

d) *Breeding Potential*

During the rut it was noticed that hinds with fawn at heel tended to stay away from breeding herds, and no conceptions of lactating hinds were recorded. In one case it was observed that a fawn intervened when a rutting stag attempted to check the hind quarters of its mother.

Non lactating hinds were found to be more frequently associated with stags than lactating hinds during the rutting period. However, this tendency was noticeable also in other seasons. Tab. 10 shows the proportion of lactating and non lactating hinds in two types of groups during the rutting period. One group type was marked by intensive rutting behaviour of at least one stag and following of estrous hinds by those. The other group type had no rutting activity. Hinds with fawn at foot were significantly less frequent in groups with rutting activity. This indicates that in general only non lactating hinds conceive. Hinds with fawn at

TABLE 10

FREQUENCY OF LACTATING AND NONLACTATING FEMALE BARASINGHA IN TWO TYPES OF GROUPS, DURING THE RUTTING PERIOD (DECEMBER 15 TO MARCH 14) 1971-73

Contingency table, $\chi^2 = 5.12$; $p < 0.05$

	Classified in groups		Total
	With rutting activity	Without rutting activity	
Hinds with fawn	24	198	222
Hinds without fawn	41	182	223

foot join the breeding groups at hours when rutting has ceased and leave them again with the onset of rutting behaviour. They may then roam along the edges of the rutting areas or join other female-young groups. This accounts for the higher proportion of adult stags in groups with rutting activity (40.6%) compared to groups without rutting activity (28.7%).

Trainer (1969) found the same phenomenon for Roosevelt elk (*Cervus canadensis roosevelti*) on poor range in Oregon. Phillips *et al.* (1973) noticed the use of heavy cover by moose cows with calves throughout the rut, indicating avoidance of bulls. Mitchell and Brown (1973) reported that the possession of a calf at foot at least reduced the probability of breeding in Scottish red deer living on poor quality hill land. Generally lower proportions of breeding with lactating hinds was also found for red deer on Rhum in Scotland by Lowe (1969).

Whether biennial conception in female barasingha is merely related to poor range conditions, as suggested for the above mentioned deer, could not be determined. Fecundity in monoestrous tropical deer may be lower in general, and still result in a similar fawn crop due to the absence of winter losses and generally low early fawn mortality, effected by

more favourable environmental conditions.

e) Rates of Population Increase

As mentioned in the previous section, we must presume that only non-lactating hinds conceive. Thus, approximately half of the hinds breed each year. Under this assumption and the unlikely case that all yearling hinds would conceive, the theoretical maximum rates of increase for 1971-73 would range between 25.4% - 26.9%. Although these rates of increase estimated from sex and age data are rough calculations, they may give an estimate of increase potential as of the time the field data were collected (Kelker 1947). However, they do not account for mortality.

The actual rates of population increase calculated from Tab. 8 were: 20.4% (1971-72) and 18.8% (1972-73). The proximity of these rates to the theoretical maximum rates indicate generally low mortality during the study period. Rates of increase on this order have been obtained in the initial growth phase for *Cervus canadensis* (Murie 1951).

5. Predation

The barasingha population in Kanha is being regulated in number entirely by natural mortality. Other than for predation, no other causes of death were evident during the study period. Hence, the question arises to what extent predation may influence the abundance of the barasingha population.

Errington (1946) indicated that under certain conditions predators may cause an effective decimation of ungulate populations; and Lack (1966) suspected that cervids in particular may be reduced by predators to a level that is below the maximum density allowed,

considering nutritional factors. In general, canids have been found to be effective predators of ungulates. It was stated by Pimlott *et al.* (1969) that the wolf may be determinative for the abundance of ungulate populations. The wolves on Isle Royal, Michigan were also found to limit the population of moose (*Alces alces*) to a level of about 600, which is below the carrying capacity determined by the vegetation on this island (Mech 1966). Little information on predator-prey relationships is available where cats may limit ungulate populations. Authors generally agree that the maximum density of cats is determined by intra-specific mechanisms, such as territoriality, rather than by the abundance of prey species (Lion: Schaller 1969; Mountain lion: Hornocker 1970; Cheetah: Eaton 1970).

In Kanha National Park the tiger is by far the most important cause of mortality in barasingha. There were no indications of predation by other carnivores or man during the study period. Schaller (1967) reported a massive loss of barasingha due to predation by tiger: In the year 1964 at least 16, out of the total population of 82 barasingha, were killed in the area of the Kanha Meadow alone. Such a rate of predation contrasts strongly with my observations: Not a single barasingha was killed in this area during my two-year study, in spite of the larger barasingha population that lived here. It must be concluded from Forest Department records and statements made by H. S. Panwar that the park's tiger population remained constant in numbers since 1964.¹¹ What then could be the cause for a lower rate of predation on barasingha in the centre of the park?

¹¹ The fact that the number of tigers in the area remained constant in spite of the massive increase of chital since 1964, suggests that the tiger has reach-

ed its maximum density, which according to the above mentioned authors, is determined by intra-specific mechanisms.

a) *Influence of Tiger Baiting*

Between 1964 and 1969 tigers were lured by buffalo bait in the Kanha Meadow, which is the centre of the barasingha's cool- and dry season range. Intensive baiting caused temporal aggregations of 5 and more tigers, though, tigers are normally solitary. It was quite common that a tigress with cubs remained sedentary near the baiting site over weeks. These tigers, however, frequently preyed upon free ranging animals including barasingha, which no doubt contributed to the high predation rate in the Kanha Meadow. During the period of this study, tigers lured by buffalo bait killed 3 barasingha, although the baiting site was relocated in a forest area about 1 kilometre distant from the Kanha Meadow after 1969. All the three kills were made in the direct vicinity of the baiting site.

This indicates that artificially caused aggregation or sedentariness of predators within the activity centre of a prey population may effect an increased rate of predation. From the example of 1964 it is plausible that such influences not only cause a decimation, but on the long run, eventually lead to the extermination of a strongly localized prey population.

b) *Relative availability of prey Species*

In the case of the barasingha population a decrease of the rate of predation since 1964 is, however, not totally explained by the relocation of the tiger baiting site outside the barasingha's activity centre. In chapter 1-3 I have commented on the massive increase of the park's chital population between 1964 and 1973. It must be expected that the proportion of chital kills increased accordingly, which possibly had an effect on the rate of predation on barasingha: Tab. 11 shows the proportion of kills of different ungulate species collected in the park area falling into Mandla District by Schaller in 1964/65 and myself in 1971-

TABLE 11

NUMBER AND SPECIES OF PREDATOR KILLS COLLECTED IN THE PART OF KANHA NATIONAL PARK FALLING INTO MANDLA DISTT.; IN 1964-65 (FROM SCHALLER, 1967) AND 1971-73 (THIS STUDY)

Species killed	Period			
	1964-65		1971-73	
	No.	%	No.	%
Chital	98	43.0	133	81.6
Barasingha	39	17.1	7	4.3
Sambar	56	24.6	9	5.5
Barking deer	1	0.4	—	0
Gaur	14	6.1	6	3.7
Black buck	2	0.9	—	0
Fourhorned antelope	—	0	2	1.2
Wild boar	10	4.4	3	1.8
Langur	6	2.6	3	1.8
Porcupine	2	0.9	—	0
Total	228	100.0	163	100.0

73. In most cases it was unknown when these kills were made. They may have also partly been caused by other predators than the tiger. The kills found in the two study periods were moreover not likely to be strict random samples of the total park area.

Nevertheless they may be used to indicate the general trend of a change in the prey ratio since 1964. Two tentative conclusions are suggested:

- 1) The proportion of chital kills increased, which reflects the increase of the chital population from approximately 1000 animals in 1964 (Schaller 1967) to more than 5000 in the same area in 1972.
- 2) The decrease of the proportion of barasingha kills is paralleled with the decrease of other species kills, particularly sambar. This suggests that the decrease of predation on barasingha is mainly due to the increased availability of chital, hence not pronouncedly due to the relocation of the tiger baiting place outside the activity centre of the barasingha.

TABLE 12

NUMBER OF TIGER FECES CONTAINING HAIR OF DIFFERENT PREY SPECIES COLLECTED IN THE INTENSIVE STUDY AREA OF KANHA NATIONAL PARK IN 1964 (FROM SCHALLER 1967) AND 1972 (THIS STUDY).

The distributions in the two samples are significantly different.

$$(\chi^2 = 50.120; \text{d.f.} = 4; p < 0.001)$$

Hair type	Period			
	1964		1972	
	No.	%	No.	%
Chital	175	52.2	241	78.5
Barasingha/Sambar	64	19.1	22	7.2
Langur	21	6.3	10	3.3
Wild boar	3	0.9	6	2.0
Other content	72	21.5	28	9.1
Total number of feces	335	100.0	307	100.0

containing chital hair, and a consequent decrease of feces containing other species' hair. These results support the above conclusions made on the basis of kills found.

Since the number of tigers in the area is likely to have remained constant, it may be concluded that the fast growing chital population has effected a reduction of the absolute number of barasingha kills. The rates of predation found in 1972 also suggest that the tiger, when naturally dispersed, preys upon the three species, chital, sambar and barasingha according to their relative abundance. Under these circumstances the tiger seems not likely to be determinative for the abundance of any one of these deer species.

VII HABITAT STRUCTURE AND ALTERATION

Although all the meadows of the intensive study area lie within the sal forest area below 610 metres a.s.l., there is an obvious difference between the grassland structures of the diffe-

Somewhat more reliable data on the proportion of tiger prey and its change since 1964 is found in the analysis of tiger feces collected in the central part of the Kanha Park by Schaller (1967) in 1964 and myself in 1972:

Tigers on their nightly prowls often go along roads where their feces may frequently be found. In 1972, a total of 307 tiger feces were collected on the roads of the intensive study area. Tiger feces may be distinguished from other predator feces by their large bore. The only other species which possibly could cause confusion is leopard, which were rare in this area. Practically all tiger feces had a major content of hair, apart from remains of soil, plant material, bones etc. The feces generally contained hair originating from only one prey species. Joslin (1972) elaborated a key for the identification of hair originating from a large number of domestic and wild prey animals living in Gir Forest (Gujarat). It was based on the external appearance and the cross-section of hair. This key and a reference collection of hair from different body parts of killed animals was used to distinguish between the hair of the main prey species of tiger in Kanha.

Tab. 12 lists species that may even be identified from external appearance of their hair. Unfortunately, I found no way to tell sambar and barasingha hair from each other with certainty, although Schaller (1967) made the distinction. Both species have hair of the same length and oval outline with complete but varying dull brown to reddish brown pigmentation; cross-sections are much alike. Thus, sambar and barasingha had to be classed together. Schaller's data were adapted accordingly. Tab. 12 shows a significant difference of the frequency of occurrence of different hair between the data from 1964 and those from 1972. It is marked by an increase of feces

rent meadows. All of the meadows are distinguished by a closed ground vegetation composed of grass species. A low grass cover composed mainly of short annual species abounds in the Kanha Meadow, whereas the meadows in the northern part are covered mainly with tall grass thickets interspersed with loose stands of trees and shrubs.

Some Cyperaceae species occur in moist depressions. Forbs are infrequent. As the annual precipitation of the Central Indian monsoon climate is practically confined to the months of June to September, there is a distinct growing period of all grass-like plants starting with the first heavy rains. The first species start flowering in August and by the month of October virtually all grasses are either in flower or seed. In this month identification of species poses no major problem. During the cool season and the following dry season the grasses increasingly dry up, first those in the open plain, later the more shade resistant species. Dried up grasses can not always be properly identified.

During the flowering periods of 1971 and 1972, specimens of all grass- and grass-like plant species occurring in the sal area were collected and identified.¹² Excepting some of the rarer species, a total of 81 grass- and grass-like plant species were found in the intensive study area (Appendix I).

In the intensive study area five principal kinds of grassland could be distinguished. They differed considerably in appearance, i.e. height and composition of species. Each of them was marked by the predominance of one or more characteristic species. These kinds of grassland will subsequently be referred to as "associa-

tions" and be labelled by their main character species:

- Association 1 — *Dimeria connivens*
- 2 — *Bothriochloa odorata*
- 3 — *Themeda triandra*
- 4 — *Ischaemum indicum*
- 5 — *Vetiveria zizanioides*

I am aware that this is a quite arbitrary subdivision, although practically every spot in the intensive study area meadows could easily be assigned to one of these associations. I will thus first describe the appearance, identity and distribution of the five associations.

It was suspected that the difference of the vegetation structure between different parts of the intensive study area was largely determined by the impact of grazing and burning (Schaller 1967; Martin 1973). Rapid alteration of the grass cover, mainly in the Kanha Meadow, was believed to influence the food potential for herbivores. In a second step I shall therefore define the impact of grazing during the growing season, and the pattern of burning. An analysis of the distribution and diversity of trees gives some further information. This leads finally to a discussion of the habitat factors that influence the barasingha's range conditions.

1. Plot Method

In October 1972, a plot method was used to sample the larger meadows within the intensive study area. Plots were 10 square metres and circular. The plot centres were marked by pacing off compass lines in north-south and east-west direction at intervals of 200 steps (Fig. 17). The plot sites received were usually within 20 steps of the location received by

¹² Identification of the specimens was made by the Indian Forest Research Institute in Dehra Dun U.P. A preliminary survey of the grassland struc-

ture in the intensive study area has earlier been described (Martin & Huber 1973).

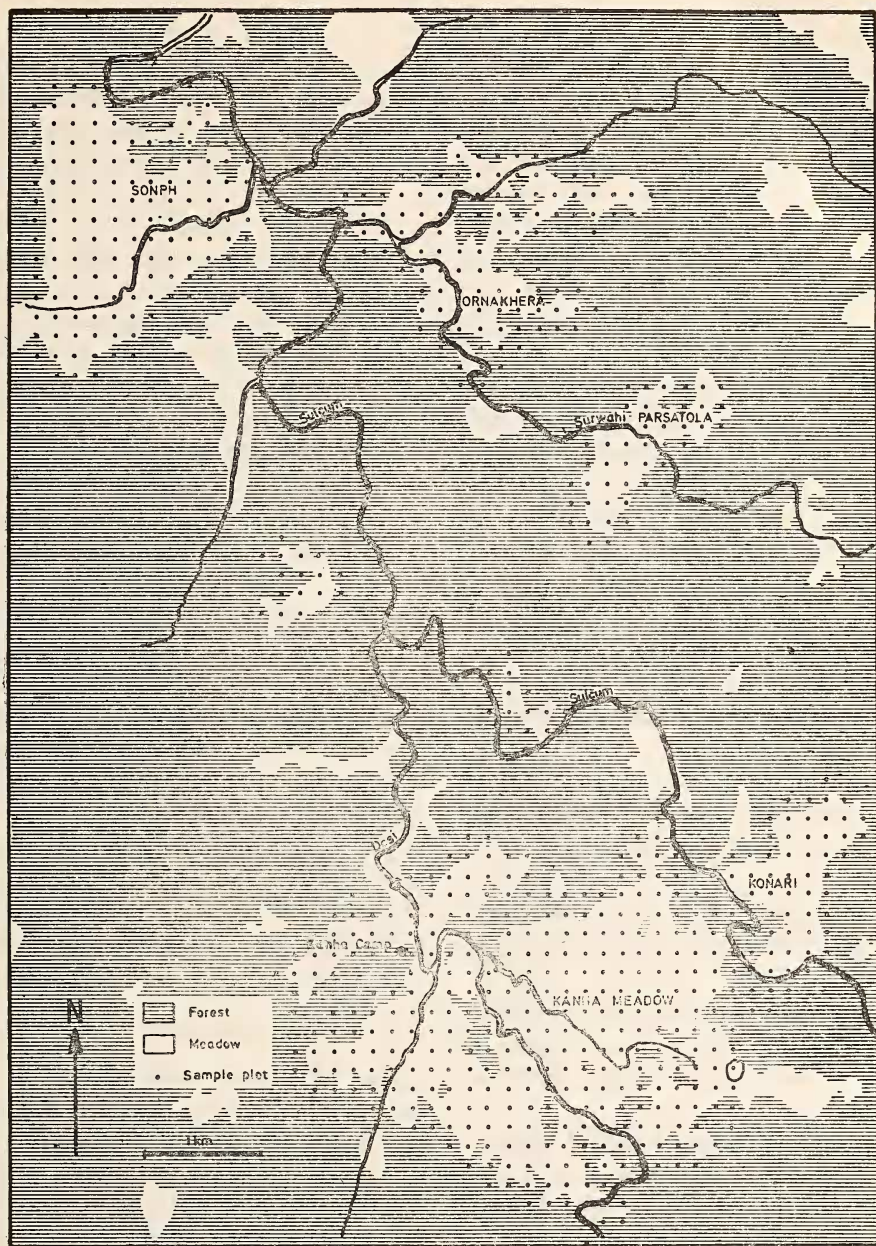


Fig. 17. Intensive study area showing distribution of sample plots for the habitat analysis.

control-pacing off from other directions. The sampling was extended into the surrounding forests by one plot on every north-south respectively east-west line. If the latter was less than 50 steps within the forest, a further plot on the line was recorded. The total number of plots was 791, of which 456 fell into meadows and 335 into forest. The number of plots that could be surveyed per hour with two helpers varied from 5 to 10, depending upon the accessibility of the terrain.

For all the plots, the plot centre was considered the centre of four quarters, with orientation given by the compass line of traverse. The species of the closest woody plant species (taller than 2 metres) to the plot centre in each of the four quarters around the centre was recorded, as well as its diameter in 5 cm intervals and its distance to the plot centre (Quarter method, see Cottam & Curtis 1956).

In the plots falling into meadow the following items were recorded:

- (1) The five predominant grass- or grass-like plant species (if five present) and the degree of their abundance (rank order).
- (2) The grassland association determined according to the occurrence of Key species.
- (3) The principal grassland biotope, distinguished by the presence or absence of shade, respectively by "high" or "low" ground moisture:
 - Dry-open—(open grassland plains)
 - Moist-open—(depressions, ravines)
 - Dry-shady—(forest edges, beneath loose tree stands)
 - Stream-bed—(often sandy, or with rocky outcrops)

Locations were valued as "moist" if the ground still had swampy character in October i.e. roughly one month after the end of the monsoon rains, later even these may dry out. Locations were considered "shady" if the plot was found to have more than 50% shade at noon.

- (4) The grass height was measured with a pole that was segmented every 5 cm. The board was put in the plot centre and read from a distance of 10 metres (Fig. 18).

- (5) Grazing incidence:

low — none or one plant grazed
 medium — two to ten plants grazed
 high — more than 10 to all plants grazed

For plots falling in the forest, the type of undergrowth (species) was recorded.

The data collected in the 228 plots of the Kanha Meadow were used to compute a correlation matrix¹³ with 35 variables. It included the correlation among the occurrence of the 24 grass species with the highest mean abundance in the Kanha Meadow; the five grassland associations; the four biotope types; the grass height and the grazing incidence. Partly, these variables were a priori interdependent. Not all correlations will thus be referred to.

2. Grassland Structure

The correlations among the occurrence of grass species helped to check and specify the distinction of the five grassland associations. Significant negative correlation ($p < 0.05$) between two species indicated that they were discretely dispersed, whereas significant positive correlation indicated that they commonly occur together. Agnew (1961) used analogous methods to show species constellation in which *Juncus effusus* occurred in North Wales.

¹³ Program BMD 02 D of the Health Science Computing Facility, UCLA.

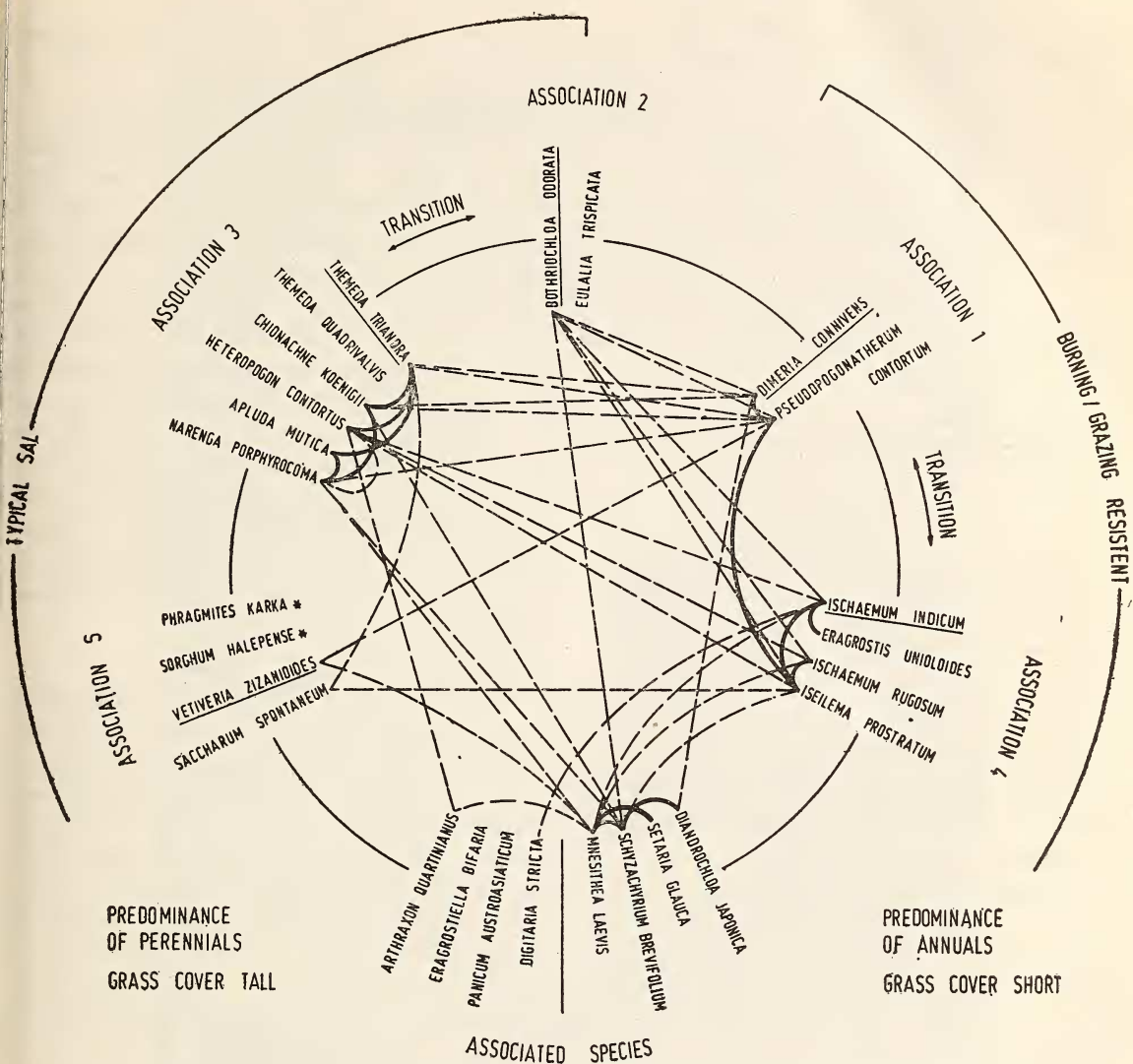


Fig. 19. Species constellation showing positive and negative correlation between the occurrence of the most common Gramineae species in the Kanha Meadow. Double line: pos. correlation ($p < 0.05$). Dashed line: neg. correlation ($p < 0.05$). Underlined species: Main character species of associations. Asterisk (*): Species not included in correlation matrix.

The correlation matrix largely confirmed the discreteness of the five associations that were distinguished initially by more subjective criteria. Fig. 19 shows the significant positive and negative correlations of the occurrence of the

most common grass species.

The adaptability of different species towards different environmental conditions varies greatly. Practically every species favours one out of the four biotope types: Dry-open, moist-

open, dry-shady and stream-bed. The number of species, however, that are confined exclusively to one of them are few. The associations, marked by the occurrence of character species, have themselves different forms of adaptability to the biotope types. Yet, no association is so adaptable as to occur in all the biotope types (Tab. 13).

TABLE 13

OCCURRENCE OF GRASSLAND ASSOCIATIONS IN DIFFERENT BIOTOPE TYPES OF THE GRASSLAND IN THE INTENSIVE STUDY AREA

× = main occurrence: (×) = secondary occurrence

Association	Biotope types			
	Dry open	Moist open	Dry shady	Stream bed
1 <i>Dimeria connivens</i>	x	(x)		
2 <i>Bothriochloa odorata</i>	(x)	(x)	x	
3 <i>Themeda triandra</i>	x	(x)	x	
4 <i>Ischaemum indicum</i>		x		
5 <i>Vetiveria zizanioides</i>				x

Figs. 20 and 21 show the distribution and appearance of the grassland associations.

Association 1 (*Dimeria connivens*):

It is most common in the Kanha Meadow where it occurs in the dry-open and moist-open biotope types. It is rarely found in other meadows. *Dimeria connivens* is a short, annual species that forms typical lawns. Its wide distribution in the Kanha Meadow gives this meadow the appearance of an English park. A very typical associate is *Pseudopogonatherum contortum*, a slightly taller annual often mixed to equal abundance with *Dimeria connivens*. Both species wither relatively soon after flowering by the end of December. The terrain belonging to this association appears very bare after burning, as these annuals completely burn up. Associated species are *Digitaria stricta*,

Iseilema prostratum, and on moist ground *Fimbristylis* spp.

Association 2 (*Bothriochloa odorata*):

It is common in the Kanha Meadow where it predominates in the dry-shady and more rarely in the open biotope types. The character species is often associated with *Eulalia trispicata*, *Diandrochloa japonica* and numerous other species. The association is very variable in its height and composition. No significant positive correlation between the occurrence of the character species and associated species was detected. However, most of the more typical associated species are perennials that reach heights of 1.5 metres or more, which clearly demark this association from association 1. Locally the character species is lacking and the association shows a transition to association 3.

Association 3 (*Themeda triandra*):

This association is infrequent in the Kanha Meadow but extremely common in other meadows, particularly Ornakhhera and Parsatola, where it occurs mainly in the dry-open and dry-shady biotope type. *Themeda triandra* locally forms almost single species stands. The grass cover reaches heights of up to 2 metres. Some common associated species are *Apluda mutica*, *Heteropogon contortus*, and *Sorghum nitidum*. Particularly in Sonph *Themeda triandra* is replaced locally on open ground by the shorter *Themeda quadrivalvis*.

Association 4 (*Ischaemum indicum*):

This association favours the moist open biotope type. It appears in terrain heavily utilized by cattle, or scattered on former rice cultivations as they are found in the Sonph Meadow. The association is poor. Further character species are *Eragrostis unioides* and *Ischaemum rugosum*. In the former ricefields of Sonph, *Manisuris clarkei* is character-

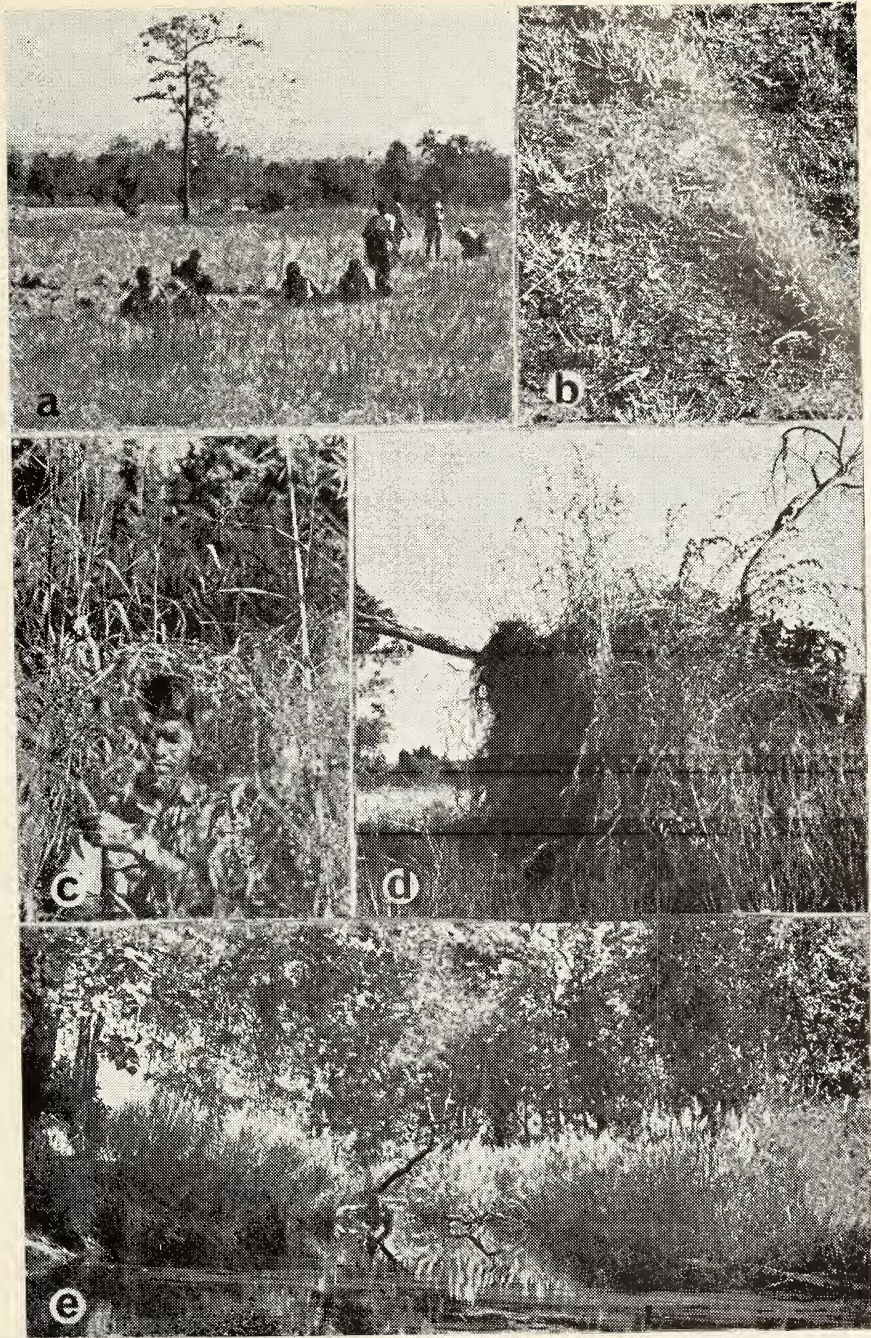


Fig. 21. Appearance of grassland in the sal forest area of Kanha N.P. (a) Short *Dimeria connivens* association in the Kanha Meadow. (b) Heavily grazed perennials in burnt area of the Kanha Meadow in May. (c) Tall *Themeda triandra* association in the Konari Meadow. (d) *Themeda triandra* persisting on a root-stock in the Kanha Meadow, where it remains unaffected by fire and grazing. (e) Stands of *Saccharum spontaneum* in a sandy stream bed belonging to the *Vetiveria zizanioides* association. The appearance of *Bothriochloa odorata* grassland is shown in Fig. 18.



Fig. 23. (a) *Moghania congesta* undergrowth in a loose patch of sal forest.
(b) Mixed forest area with bamboos (*Dendrocalamus strictus*).

STATUS AND ECOLOGY OF THE BARASINGHA

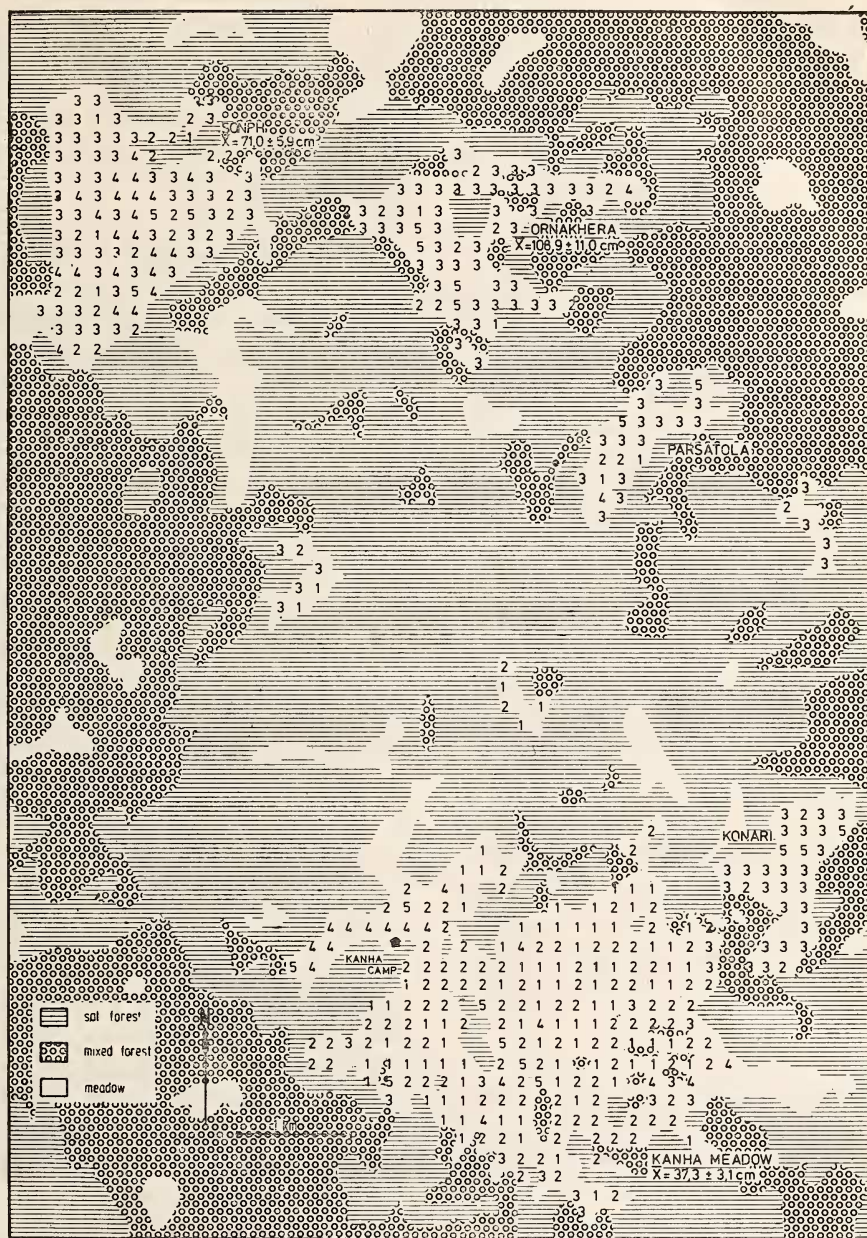


Fig. 20. Vegetation of the intensive study area. Numbers indicate grassland associations in the sample plots: 1—*Dimeria connivens*; 2—*Bothriochloa odorata*; 3—*Themeda triandra*; 4—*Ischaemum indicum*; 5—*Vetiveria zizanioides*. \times = means grass height of respective meadows with 95% confidence intervals for the mean.

istically found in the association. It is possibly derived from other associations, as it is composed of species that are otherwise not very common but resistant to heavy grazing. The association shows transition to association 1.

Association 5 (*Vetiveria zizanioides*):

This association is characteristic for the terrain along sandy and rocky river beds (Biotope type: stream-bed). It forms a belt from 5 to 15 metres wide along rivers, the width depending upon the slopes of the bed. It can, however, occur with more extensive, extremely tall grass thickets in locations that are partly flooded during monsoon. *Sorghum halepense* and *Phragmites karka* two very tall species, as well as *Bothriochloa kuntzeana* are characteristic. *Saccharum spontaneum* forms dense thickets, which remains green even in the dry season. *Phragmites karka* and *Sorghum halepense*, the tallest species, have in the past years disappeared from the Kanha Meadow, where the association remains recognisable by the dense stands of *Saccharum spontaneum*.

The fidelity of different character species to the respective association can vary greatly. Whereas the character species belonging to association 5 have a very strict fidelity, that is, they are confined exclusively to that particular association, the character species of the association 1 and 2 have a lower fidelity to their association.

Some species are very tolerant, such as *Saccharum spontaneum*. This species may occur in every association or biotope type. Yet, it abounds only along stream beds, where it forms monotypic stands. Other species are confined to one of the biotope types rather than to any particular association: Cyperaceae species occur only on moist ground. *Mnesithea laevis* occurs practically everywhere in the dry open biotope type of the Kanha Meadow. This spe-

cies is often the only medium sized perennial species that grows in the short *Dimeria connivens* association.

Narenga prophyrocoma, a very tall species, was considered to be indicative for sal-forest ground by Bor (1958).

Grass height:

The unequal distribution of the grassland associations among the meadows of the intensive study area cause drastic differences in the mean grass cover height of these meadows (Fig. 20). The predominance of the short *Dimeria connivens* association in the Kanha Meadow is reproduced in the low mean grass height of 37.3 ± 3.1 cm.¹⁴ In Sonph, where this association is practically absent, the grass reaches a mean height of 71.0 ± 5.9 cm, whereas in Ornakhara the mean height is 108.9 ± 11.0 cm. This is caused by the predominance of the tall *Themeda triandra* association.

3. Grazing Impact during the Growing Season

Grazing incidence is clearly recognizable as long as the grasses or parts of them are green. The plot method gave information on the pattern of utilization by herbivores during the growing season.

Due to grazing incidence that arose during the sampling period (October 5 to November 7), the grazing impact on the plots checked first is only to a limited extent comparable to that in the plots checked last. However, the main intention was to compare the grazing impact on the Kanha Meadow with the remaining areas. Parts of the Kanha Meadow were therefore sampled alternating with other areas.

Fig. 22 shows the distribution of grazing incidence in the intensive study area. It is

¹⁴ 95% confidence intervals for the mean throughput. Intervals are given by $\bar{X} \pm t \frac{s}{\sqrt{n}}$; at $\alpha = 5\%$

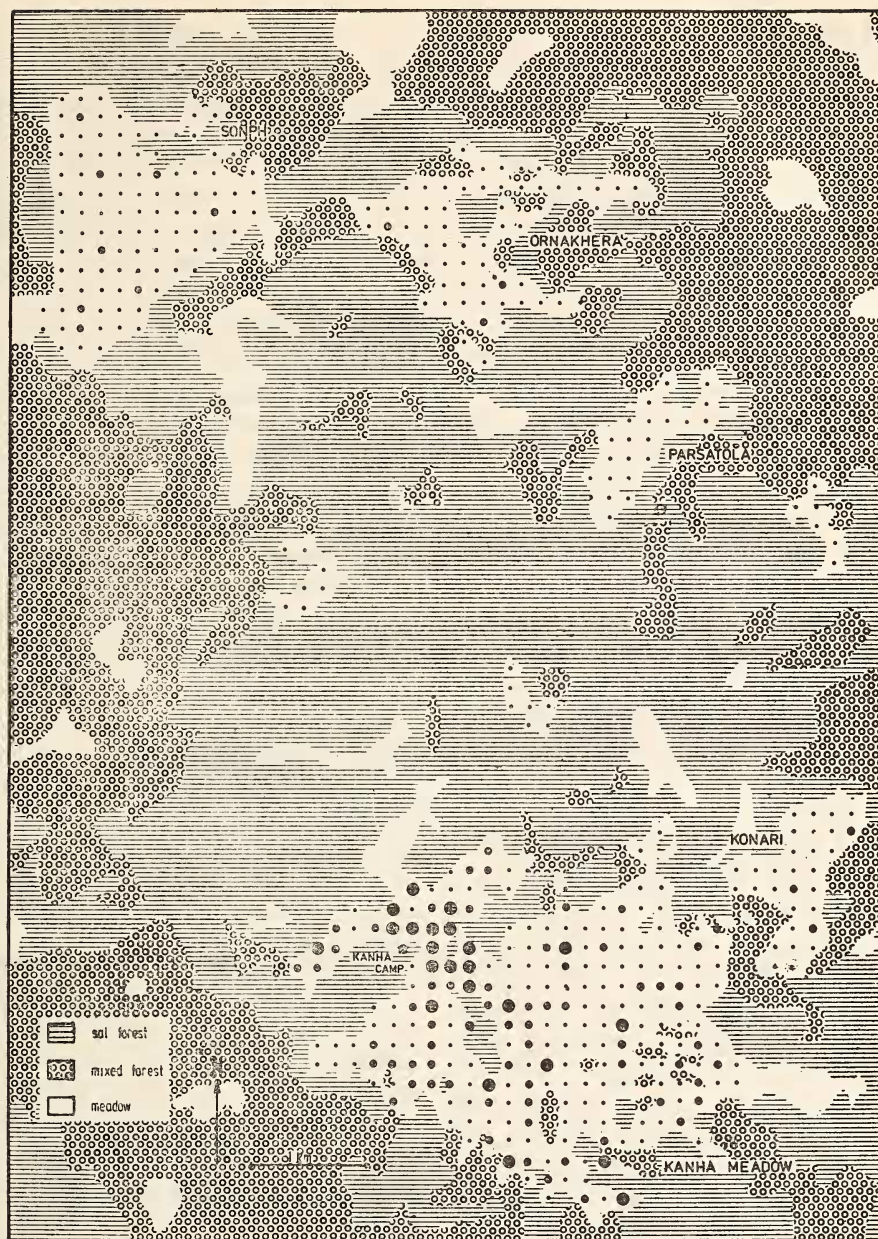


Fig. 22. Distribution of grazing incidence arising during the growing season in the intensive study area. Small dot: 0—1 plant of 10m²—plot grazed; Medium dot: 2—10 plants of 10m²—plot grazed; Large dot: 11—all plants of 10m²—plot grazed.

concentrated on the Kanha Meadow. Of the 228 plots in this meadow 38.2% had distinct signs of grazing (2-10 plants grazed), and 10.1% of the plots were heavily grazed (more than 10 to all plants grazed) by the end of the growing season. The grazing impact on all other meadows was relatively low and the infrequent occurrence of grazed plots did not allow correlation of grazing incidence with features of the grass cover.

In the Kanha Meadow, on the other hand, two species, *Bothriochloa odorata* and *Themeda triandra* seemed to be subject to constantly heavier grazing than other species. The correlation between grazing incidence and the occurrence of single species revealed that the pattern of grazing and avoidance is widely determined by the presence of certain species. The selective grazing pressure on *Bothriochloa odorata* was confirmed by a highly significant positive correlation coefficient (Tab. 14). Positive, but lower than subjectively expected correlation between grazing and the occurrence of *Themeda* spp. Yet the sampling intensity of the *Themeda triandra* association in the Kanha Meadow was low (only 14 plots). The correlation for these species might have resulted in higher coefficients if sampled more intensely. Significant positive correlation was however found for *Setaria glauca*. This annual occurs in various associations, often forming small "facies". Its positive correlation with grazing incidence did not correspond with the investigator's subjective impression, it may hence be an artefact. A significant negative correlation, which means avoidance, could be shown for *Pseudopogonatherum contortum* and *Schizachyrium brevifolium*. Both species, but particularly the former are common in the *Dimeria connivens* association. The species *Dimeria connivens* itself is negatively correlated, however, with a non-significant coefficient.

TABLE 14

CORRELATION OF GRAZING INCIDENCE WITH THE OCCURRENCE OF GRASS SPECIES. GRAZING INCIDENCE CAUSED BY UNIDENTIFIED HERBIVORES DURING THE GROWING SEASON

Coefficients $|r| \geq 0.130$ are significantly different from 0. ($p \leq 0.05$; d.f. = 226)

	r
<i>Apluda mutica</i>	0.0422
<i>Arthraxon quartinianus</i>	0.0734
<i>Bothriochloa odorata</i>	0.3241
<i>Chionachne koenigii</i>	0.0273
<i>Diandrochloa japonica</i>	-0.0489
<i>Digitaria stricta</i>	0.0398
<i>Dimeria connivens</i>	-0.1141
<i>Eragrostiella bifaria</i>	-0.0489
<i>Eragrostis unioides</i>	0.0791
<i>Eulalia trispicata</i>	-0.0527
<i>Heteropogon contortus</i>	0.0482
<i>Ischaemum indicum</i>	0.0882
<i>Ischaemum rugosum</i>	-0.1143
<i>Iseilema prostratum</i>	-0.0515
<i>Mnesithea laevis</i>	0.0757
<i>Narenga prophyrocoma</i>	-0.1055
<i>Panicum austroasiaticum</i>	0.0096
<i>Pseudopogonatherum contortum</i>	-0.3026
<i>Saccharum spontaneum</i>	0.0253
<i>Schizachyrium brevifolium</i>	-0.2280
<i>Setaria glauca</i>	0.1611
<i>Themeda quadrivalvis</i>	0.0995
<i>Themeda triandra</i>	0.0774
<i>Vetiveria zizanioides</i>	-0.0489

Associations are named after single species. The correlation of associations with grazing incidence is thus a prior dependant upon the grazing incidence on single species. Hence the *Bothriochloa odorata* association showed significant positive correlation, whereas the *Dimeria connivens* association showed significant negative correlation.

4. Burning

As in other tropical grasslands, fires must have occurred in the park's meadows since

their existence. According to Walter (1964) it is beyond all doubt that even in unpopulated tropical areas lightning can set withered vegetation afire. Natural fires, however, occur sporadically and do not necessarily frequent the same areas annually.

Brander (1923) mentioned that he had burnt the Kanha Meadow in the cool season of 1902-03 for the first time. Since then the Kanha Meadow has probably been subject to annual burning. The Forest Department used to set patches of the meadow afire from December to January until practically the entire meadow was burnt. Fires sweep the dry grass cover quickly but do not enter the forest as the vegetation in shady locations is still green in the cool season. Later during dry season occasional fires caused by villagers may also sweep the undergrowth of wide forest tracts. Living trees, however, are not affected, even when fires occur in the driest period of the year.

Fires destroy annual grasses completely, perennials survive with blackened stubble. Extensive burning practices were justified with the argument that the new sprouts, which come up sooner in the burnt areas than in unburnt ones, are for the benefit of the grazing ungulates. This shall be given consideration below.

(1) Burnt areas:

In the cool season of 1971-72 parts of the Kanha Meadow were burnt on the 19th and 23rd December, 1971. The remaining areas of the Kanha Meadow were then set afire on the 15th January 1972. Thereafter, only a few patches totalling not more than one tenth of the meadow remained unburnt. Sprouts shot up in the remaining stocks of perennials, benefitted by the short winter showers of February 2nd and 23rd. Masses of chital came to graze on the sprouts during

that period. A survey made on 7th March 1972, 50 days after burning, revealed that from 145 perennial grass stocks selected at random, 40% had been grazed upon. In May grazing incidence in the stocks could not be identified anymore. Most of the sprouts had been grazed down completely, the others had again dried up (Fig. 21).

(2) Unburnt areas:

In unburnt areas green sprouts started growing later than in burnt areas. Yet, being less exposed to grazing due to the availability of dry material, they reached heights up to 40 cm by the end of May.

In 10 plots of 5 sq metres selected at random in unburnt areas of the Kanha Meadow the grass was cut 5 cm above the ground and collected on May 27, 1972. In every sample the green sprouts were separated from the dry material. Both parts of the samples were dryweighed (air dried). The mean total dryweight per sq metres surface amounted to 129.5 g (55-240 g), of which 9% (3.9-21.5%) were recently grown sprouts. Although new sprouts were inferior in number they gave the unburnt zones a flush of green even during the driest period of the year.

Thus, whereas in burnt areas the green sprouts have a short life, due either to grazing or their drying up, unburnt areas not only keep a permanent stock of dry fodder, but produce an increasing amount of green material. The situation in burnt zones turns worse during the course of the hot season until practically no fodder may be found.

A difference in the grass height between burnt and unburnt areas remains visible in the Kanha Meadow even after the growing season following the fires. Fig. 18 shows a distinctly higher grass cover on the unburnt side of a boundary where the fire was put out eleven months ago. Such differences remain visible

mainly in those grassland associations that are predominantly composed of taller perennial species: namely the *Bothriochloa odorata* and *Themeda triandra* association. In the *Dimeria connivens* association, where small annuals reach high abundance, differences between burnt and unburnt areas are indistinct after the next growing season. In homogeneous areas, however, difference could be detected by the lower density of inflorescences of perennials in previously burnt areas.

In other meadows of the intensive study area the difference between burnt and unburnt areas did not persist over the next growing season. This could be ascribed to the lower grazing pressure in these areas. Perennials after burning suffer less damage from grazing, hence recover better.

5. Tree density and succession

In the intensive study area 60 woody plant species were recorded. Appendix II lists their frequency in different habitat types. A relatively small number of tree species is found regularly in the meadows, where they occur singly or in loose stands. The most important species on open ground are *Butea monosperma* and *Ziziphus jujuba*, two small trees. *Bauhinia racemosa*, *Cordia mixa*, *Cassia fistula*, *Diospyros melanoxylon*, *Bombax malabaricum* and *Ficus* spp. occur scattered in all the meadows. Along sal forest edges abound *Lagerstroemia parviflora*: tall specimens of *Shorea robusta* (sal) and *Terminalia tomentosa*. They are typical forest species and are scattered, thus point to the former occupation of these meadows by woodland.

The "Quarter method" applied in sampling the meadows allowed the comparison of the density of tree stands in different meadows (Tab. 15). The Kanha Meadow is distinguished by a low tree density. Trees are mostly

TABLE 15

ESTIMATION OF TREE DENSITY IN MEADOWS OF THE INTENSIVE STUDY AREA (AFTER COTTAM & CURTIS 1956). TREES AND SHRUBS TALLER 2 METRES

Meadow	Individuals per ha	Percentage of trees with less than 15 cm stem diameter	Percentage of typical forest trees (<i>Shorea robusta</i> and <i>Terminalia tomentosa</i>)
Kanha Meadow	17	44	5
Konari	36	28	12
Sonph	42	78	16
Ornakhera	90	69	30
Parsatola	76	73	3

more than 15 cm in stem diameter and are not typical forest species. The more northerly meadows have higher tree densities. However, the majority of trees are small or young. Typical forest species are more abundant than in the Kanha Meadow.

The forest tracts adjacent to the meadows were classed into sal forest or mixed forest according to the occurrence of the *Shorea robusta* (sal). The transition between the two types is generally abrupt.

(1) In sal forest areas, the sal tree makes up 52-55% of all trees above 2 metres in height. Sal trees grow about 30 metres high and up to 1 metre in trunk diameter. The main associates of the sal tree are *Terminalia tomentosa*, *Syzygium cumini*, *Mallotus philippinensis* and *Ougeinia cojeniensis*. The predominant undergrowth is formed by a shrub- *Moghania congesta*. Bamboo (*Dendrocalamus strictus*) occurs in pockets or on slopes (Fig. 23). Around the Kanha Meadow and Konari, in the southern part of the

intensive study area, the sal forest is older than in the northern part. There appears to be no widespread regeneration. This accounts for the lower density of 181 trees above 2 metres height per ha in the southern part, compared to the surrounding areas of Parsatola (255 trees per ha), Sonph (524) and Ornakhera (613).

(2) Mixed forest occurs at the edges of the Sulcum Basin above 610 metres altitude and on hillocks in the basin. The main tree species are *Terminalia tomentosa*, two other *Terminalia* spp., *Anogeissus latifolia* and *Bauhinia* spp. The tree species occurring in mixed forest areas are largely the same as in sal areas, there is, however, no distinct predominance of one species. Bamboo (*Dendrocalamus strictus*) is found in great abundance and forms thickets up to seven metres high (Fig. 23). As in sal forest areas, the mixed forest in the southern part of the intensive study area is less dense (251 trees taller 2 meters per ha) compared to the surrounding areas of Parsatola (273), Sonph (613) and Ornakhera (524).

6. Hypothesis

In this chapter I have tried to discover factors that influence the range conditions in the barasingha habitat. The habitat analysis disclosed that the northern part of the intensive study area, which was subject to lower impact by herbivores and less rigid burning practices than the southern part, has more sal regeneration, taller grass cover, younger and denser tree stands in the meadows including more typical forest trees. Some clearings at the edges of the sal area in the north, i.e. Jamuntola or Ornakhera have been so densely overgrown with trees that locally it is difficult to draw a line between forest and meadow. There are signs of reoccupation of meadows by forest.

The Kanha Meadow, being the exponent of the southern intensive study area, is different from the other open areas by a remarkably lower grass cover, brought about by the predominance of the meagre *Dimeria connivens* association. Yet the Kanha Meadow harbours more and better perennial watering places than any other area.

It has been conjectured that the exceptional shape of this meadow is a stage of a rapid alteration of the vegetation. The influence of herbivores over the structure of vegetation was suspected earlier: In 1943 a part of the then sanctuary had been opened to shooting again, as it was feared that the heavy browsing pressure could hinder the sal regeneration. Puri (1960) states that even if sal seedlings are present, their establishment is problematic. According to him the establishment period takes 10 to 30 years. The sal seedling is evidently more threatened in a densely populated wildlife area, where there are heavy browsers. The fact that most clearings within the intensive study area have not been overrun by the sal forest again was, however, also attributed to frosts and fires. Panwar (1973) states: "Without the shelterwood, the frost plays an inhibitive role and has stopped sal from restocking these areas (the meadows). Also the late fires are responsible for maintaining the grassy condition of the meadows because they destroy seedlings of pioneer species like *Terminalia tomentosa* which could otherwise grow to provide low shade, causing decimation of grass and thereby improving conditions for sal to come up."

Bor (1958) wrote that the number of grass species which withstand annual burning is surprisingly low. Schaller (1967) supposed that *Themeda triandra* had largely been replaced by annuals or other perennials in the Kanha Meadow. And according to statements

from local people the grass cover grew consistently taller on the Kanha Meadow some ten or twenty years ago. *Themeda triandra* was common, and the rivulets were bordered by tall species such as *Sorghum halepense* and *Phragmites karka*, whereas today these species are extremely rare in the Kanha Meadow.

Thus it seems realistic to suppose a firm relationship between the present habitat structure and the impact of grazing and or burning, which are known to be effective mechanisms that alter the vegetation.

The following considerations may shed light upon the character of grassland changes and their consequences. I am aware, however, that long term exclosure experiments under controlled conditions could reveal more exact information.

Burning reduces the food availability during the dry season. Yet, the Kanha Meadow which has been burnt annually since the beginning of this century, attracts ungulates during this season, due to better water conditions. Thus, apart from the influence on the grass cover caused by burning alone, the grazing pressure on the Kanha Meadow in the period after burning remains high. Yet, in an area that has a reduced quantity of food, the impact of grazing and trampling by a given number of ungulates is disproportionately more severe, than it would be in an area with large quantities of food. After burning it is the remains of perennial species that are exposed to heavy grazing. Particularly the protein rich sprouts that are induced in perennial grass tufts by burning attract the ungulates. During the growing season the main grazing pressure is still put on a few perennial species which are important constituents of the mainly perennial associations, whereas the mainly annual associations are avoided.

Consequently many taller perennials such

as *Bothriochloa odorata*, *Themeda triandra*, *Sorghum nitidum*, *Eulalia trispicata* often do not reach the flowering stage in the Kanha Meadow. Suppressed perennials are characteristic for this meadow. It may thus be postulated that the combined effect of burning and heavy grazing is the mechanism responsible for the disappearance of these taller and more leafy perennials. Consequently, small annuals such as *Dimeria connivens*, *Pseudopogonatherum contortum* and *Schizachyrium brevifolium* and more resistant perennials, like *Mnesithea laevis* have gained ground. Suppressed tall perennials and the predominance of the *Dimeria connivens* association affect the low mean grass height of this meadow. *Themeda* spp., which predominate in all other meadows, occur today in the Kanha Meadow merely along forest edges that are not affected by early burning, or in other places that are not subject to regular burning and heavy grazing (Fig. 21).

Ultimately we may consider the effects of burning and grazing discussed here, when joined into a model where ungulate density, food and water initially keep in a state of equilibrium (Fig. 24). Applied to the Kanha Meadow, the ungulate density is kept high due to water availability during the dry season or even promoted by the attraction caused by green sprouts after burning. In the long run the availability of the food decreases and may lead to severe overgrazing. Symptoms of overgrazing are in fact obvious in the Kanha Meadow during the dry season. However, they are mainly confined to perennials.

Spence & Angus (1971), who made a detailed study of two grassland communities in Murchison Falls National Park, distinguished precisely between the effects of burning and grazing. They have also come to the conclusion that these two factors have a combined influence on the grass cover. Pienaar (1966)

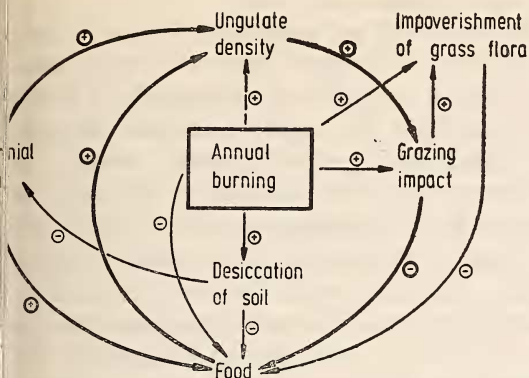


Fig. 24. A model showing the influences of annual burning on herbivore food availability.

described rotational burning practices in Kruger National Park and commented on the danger of overgrazing in the case of annual burns, particularly in the vicinity of watering places. Walter (1964) listed among disadvantages of annual burning in tropical zones:

- Loss of organic material to soils, already poor in humus.
- Unprotected surface against erosion at the beginning of the rainy season and run-off of waters with consecutive promotion of desiccation.
- Washing away of the minerals contained in the ashes.

Annual and extensive burning in densely populated grassland areas that harbour permanent watering places seems thus not to be justified. It must be replaced by rotational burning of blocks and effective protection of unburnt areas by means of fire breaks. Whether triennial rotational burning or longer intervals are the adequate measure has yet to be clarified. In the Kruger National Park areas around permanent water supplies are permanently protected from fire (Pienaar 1968). In Kanha National Park Fire protection measures were introduced in 1972. A further consequence of

annual burning might be the considerably lower density of small rodents found by Claude (1973) in the Kanha Meadow, compared with the open areas of the northern intensive study area.

The Kanha Meadow is the centre of the barasingha's cool and dry season range. There is no interspecific avoidance between the major users—chital, and barasingha (mixed herds); on the contrary it was found that the same areas within meadows are subject to heavy exploitation by both species. Overgrazing must therefore affect also the barasingha's living conditions. All the more, so, because the barasingha live almost exclusively from grasses.

VIII DISCUSSION

The original aim of this study was to collect data for an ecological understanding of the factors that determine the living conditions of the barasingha in Kanha—its dispersion and abundance.

Perhaps the most striking fact in the ecology of this species is the practically exclusive grass diet throughout the seasons. The barasingha subsist from grasses to such an extent, that it must be rated a rare event if a barasingha is observed feeding from other resources. It appeared that the barasingha's peninsular distribution was largely restricted to moist deciduous—or more precisely—to sal forests. The fact that the graminivorous barasingha was at all able to colonize these forests must be attributed to the rich grass flora typical for the undergrowth, and open space in level ground sal forests. Shifting cultivation practiced by local tribes opened up the forest, which benefited the barasingha. The Kanha population is an example of this. The barasingha's existence in this park is based on grassy open areas formerly caused by the shifting cultivation of

Gond and Baiga tribes.

1. Adaptations to the Central Indian environment

The archaean physiographic features of the Central Indian Highlands imply a grassland type that is quite different from those in the alluvial plains of northern and northeastern India. The peninsular rivers are entirely fed by monsoon rains and are, therefore, more or less dry during the dry season. Rivers in Central India moreover eroded vertically and are characterized by the absence of riparian flats and marshes, so typical for the geologically younger Ganges—Brahmaputra river system. Other than in these northern habitats, where flood land supplies lush green grass throughout the seasons, the grassland in Central India is characterized by a more distinct seasonality and a long dry period.

Seasonality is subsequently much more pronounced in the way of life of the typical grass feeder. The barasingha has to adapt to seasonally different food—and water conditions by wandering. It should not be surprising then that the Central Indian population shows a strictly seasonal migration pattern, whereas such elements are absent in the northern populations. In Kaziranga, Assam, the barasingha remain so sedentary around perennial pools (locally: bheels) throughout the year, that Ullrich (1972) was misled to speak of "territoriality". Brander (1923) reported migratory habits of the wild buffalo in Central India, which suggests that adaptation to seasonally different food and water conditions by wandering occurred also in this species. Wild buffalo essentially require the same habitat as barasingha. It is also remarkable that the barasingha in Kanha were most sedentary during the growing period of the grass flora, when the food conditions resembled those at the foot

of the Himalaya the most.

It was found that grouping habits are largely a function of environment. Low group stability reflects adaptation of individuals to locally different food and water conditions. Whereas the patchy distribution and local scarcity of resources causes very frequent break-ups of groups in Central India particularly during the dry season, barasingha in the more homogeneous, nutritious grasslands and marshes of northern and northeastern India would be expected to form more lasting associations. Although so far there have been no detailed studies on grouping in the northern populations, observation of barasingha in Kaziranga, Assam strongly support this view.

Thus, it may be concluded that the barasingha's post-tertiary colonization of Central India with its changed environmental conditions had fundamental consequences on the way of life of the species. If the disappearance of the barasingha in Central India is considered, this should be done also in view of these environmental consequences!

2. Relevance to the decline

Retrogressive trends in mammalian distribution patterns are of geologically recent origin, they indeed date back to historical times (Mani 1974). Even the present-day discontinuity in mammalian distribution between the Sub-Himalayan plains and the Peninsula is no more than a relict of a former continuous distribution (Kurup 1974). Destruction of habitat, cultivation and predation by man were the chief causes for these retrogressive trends. It also stands to reason that, where forests remained at all, the grassland species were far more exposed to the pressure of man, than the forest inhabitants. Apart from the barasingha, the Indian gazelle (*Gazella gazella*), the blackbuck (*Antilope cervicapra*), the wild buffalo (*Buba-*

lus bubalis) and the great Indian rhinoceros (*Rhinoceros unicornis*) are all more or less endangered or have reached the verge of extinction. The cheetah (*Acinonyx jubatus*) disappeared from India in 1951 (Talbot 1960).

However, none of the detrimental, man-induced influences would have effected the drastic decline of the barasingha in the area of the present Kanha National Park. If it would not have been in combination with the migratory habit that was generated by the Central Indian environmental conditions.

Before the 1964—enlargement of the park, the barasingha's annual range must have reached far beyond the northern park boundaries into ordinary shooting blocks. Villagers from settlements near the park reported barasingha raiding their crops. Even earlier, between 1943 and 1952 the area lying to the west of the Kanha-Sihora Road also had the status of a shooting block. It comprised the lower part of the Sulcum Valley which embraces the major part of the populations present home range. Until 1969, moreover, the meadows in the northern part of the home range were seriously affected by the settlement in Sonph and the accompanying activities of men and cattle. This means in other words, that until this very late date, the 6-square-kilometre Kanha Meadow was all that existed of suitable, unencroached habitat for the barasingha. Its dispersion, however, was never restricted solely to that area. The lack of group stability was likely to have promoted the dispersal of individuals from the population's home range, which incidentally led to casualties in more distant areas. It remains unknown where the pregnant hinds gave birth during these times. Fawning sites in disturbed or very distant areas might have caused high early fawn mortality, which would give an alternative explanation for the low fawn rate found by Schaller (1967), who postu-

lated that brucellosis might be the cause.

Losses caused by all sort of human predation, emigration effected by men and cattle activities or deteriorated habitat, absence of suitable fawning areas, and perhaps detrimental habitat influences on the natality of the population, therefore were the ultimate reasons for the steady decline of the standing population in Kanha until the nineteen sixties. The species, by now, would possibly be totally absent from Central India, had the Kanha Meadow not have been under rigid protection since 1935. Diseases on the other hand were most probably insignificant. One would expect oscillation of the population numbers if disease was to play an important role in the history of the decline. Brander (1923), moreover, found the barasingha to be resistant towards cattle diseases. Even if the earlier population was taken with brucellosis, as Schaller (1967) suspected, this could not have contributed relevantly to the more or less steady decrease that has continued over dozens of years.

Concisely, the barasingha of Kanha National Park until recently were by no means free from those detrimental factors that were known to have led to the extinction of all other barasingha populations in Central India, namely habitat destruction and predation by man. Also, the habitat requirements of the species and its adaptations to the Central Indian habitat conditions in general promoted the decline.

3. Response to present conditions

During the period of this study the population was increasing. Censuses carried out by the Forest Department in 1973-75 documented a continuation of the increasing trend after the Field phase of this study was completed (Panwar, personal comm.). The reproductive success of the population was found to be well within the limits of a normal production in

monoestrous deer with 26.7-41.2 fawns/100 females, tallied more than half a year after the fawning season. The population in 1973 was remarkably young with 36.0% of the males being less than 2 years, and 46.3% being less than 3 years old.

In fact the population increase seems mainly to be based on an increase of the reproduction success since the nineteen sixties and low mortality in the fawn class. Both these factors may be interpreted as a response to more favourable environmental conditions. Those were brought about by the increase in suitable habitat after the enlargement of the park in 1964 and the ban of human and cattle activities from the northern part of the populations' composite home range in 1969. Subsequent fire management, anti-poaching control, and improvement of water conditions added to the suitability of the available grassland habitat. A somewhat lower rate of predation by tiger since the outbreak of the chital population, which acted as a "buffer" prey, may have stimulated the increase. Although, tiger predation under normal conditions seems not likely to be determinative for the abundance of the deer species in Kanha.

We may thus conclude, that the population is best secured if management tends towards incorporation into the park and improvement of grassland habitat in level ground sal forest areas. This is all the more so, since habitat alterations and competitive exploitation caused by the former rigorous burning practices and the fast growing chital population impend over the park centre's Kanha Meadow.

IX SUMMARY

The barasingha of Kanha National Park are the last in Central India. A drastic decrease of the population since the beginning of this cen-

tury has led to this study. At the beginning of the study period (April 1971 through April 1973) the population numbered less than 100 animals.

The population's range during the study period included 47 square kilometres of the sal forest area below 610 metres elevation in the Sulcum River Basin. Within this area the dispersion was found to be largely restricted to grassy meadows throughout the year. The population congregated in the southern part of its annual home range around the Kanha Meadow during the cool- and dry season (December 15 to May 31). This area was found to have the best water conditions. During the monsoon rains the population dispersed along the course of the Sulcum River into the meadows of the northern part (growing season range). The Sonph Meadow was entirely undisturbed by human activities since 1969. In contrast to earlier times it was found to constitute the main activity centre during the growing season.

During the cool- and dry season the barasingha showed synchronized diurnal activity patterns. Feeding activity occurred in bouts around sunrise and sunset and travelling was more pronounced then during the rest of the year. This was ascribed to relative scarcity of food and water during this period of the year, and the search for shady resting sites.

The utilization pattern during the cool- and dry season was found to be governed by the availability of open rivulet zones and unburnt patches of grassland. During the growing season the barasingha were practically confined to tall grass areas along rivulets.

The barasingha was found to be exclusively graminivorous. The cool- and dry season food included mainly green perennial grasses e.g. *Saccharum spontaneum*, *Bothriochloa odorata* and *Themeda triandra*. During the growing

season a broader variety of species was eaten.

A modified pellet count technique revealed a correlation of barasingha- and chital (*Axis axis*) pellet frequencies which suggested common utilization of open grassland. This was further supported by the frequent observation of mixed barasingha - chital herds. The sambar (*Cervus unicolor*) on the other hand seemed to utilize the meadows differently.

Mean monthly group sizes varied between 3.7 and 13.1 animals/group. In February and March, at the end of the rutting season, the largest aggregations were observed. Except during the rut grouping seemed to be largely determined by environmental factors. Females with fawn at the foot and yearlings tended to remain in open areas more than other classes. Except for the association of the hind with her fawn in its first year the barasingha formed no lasting associations.

During the study period the population increased from an estimated 93 animals in 1971 to an estimated 133 animals in 1973. A comparison with data collected by Schaller (1967) showed, that sex ratios remained more or less constant since 1964-65. In the fawn and yearling classes it was 1:1, whereas it was about 75 males to 100 females among adults. However, the population as a whole was considerably younger during this study period compared to 1964/65. In 1973 36% of the males were less than 2 years old and 46.3% were less than 3 years old. This was due to a higher fawn production, which ranged between 26.7-41.2 fawns/100 females, and generally low mortality in the younger age classes. The rate of tiger predation on barasingha decreased since 1964/65 according to an increase of the availability of chital and the relocation of the tiger baiting site outside the barasingha's activity centre.

A vegetational analysis determined influ-

ences of grazing and burning on the appearance of the grassland in the sal forest area. The present appearance of the Kanha Meadow was widely derived from the influence of these two factors. Future management suggestions are given.

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APPENDIX I

GRASS-LIKE PLANT SPECIES OF THE SULCUM RIVER BASIN IN KANHA NATIONAL PARK

Species		Occurrence	Frequency	
			Kanha Meadow	Other meadows
GRAMINEAE:				
<i>Alloteropsis cimicina</i>			—	—
<i>Andropogon adsarioris</i>			+	+
<i>Apluda mutica</i>	p	Ds (Do, Mo, Ws)	++	+++
<i>Apocypis vaginata</i>	a	Do	++	—
<i>Aristida adscensionis</i>	a, p	Ds	+	+
<i>Arthraxon quartinianus</i>		Mo (Do, Ds)	++	++
<i>Arundinella bengalensis</i>			—	—
<i>Bothriochloa glabra</i>	p		+	+
<i>Bothriochloa kuntzeana</i>	p	Ws	+	+
<i>Bothriochloa odorata</i>	p	Do, Ds (Mo)	+++	+++
<i>Bothriochloa pertusa</i>		Do	++	++
<i>Brachiaria ramosa</i>			+	+
<i>Capillipedium parviflorum</i>		Ds	+	+
<i>Chionachne koenigii</i>	p	Mo (Do, Ds)	++	++
<i>Chloris dolichostachya</i>	p	Ds	++	+
<i>Chrysopogon fulvus</i>		Do (Ds)	++	+++

STATUS AND ECOLOGY OF THE BARASINGHA

Species		Occurrence	Frequency	
			Kanha Meadow	Other meadows
<i>Cleistachne sorghoides</i>	p		+	+
<i>Coix lacryma-jobi</i>	a, p	Mo	+	-
<i>Cynodon dactylon</i>	p	Do	-	++
<i>Cymbopogon martinii</i>			-	-
<i>Dendrocalamus strictus</i>		Ds	-	-
<i>Diandrochloa japonica</i>		Do	+++	++
<i>Diectomis fastigiata</i>		Do	++	-
<i>Digitaria adscendens</i>			-	-
<i>Digitaria stricta</i>		Do (Mo, Ds)	+++	++
<i>Dimeria connivens</i>	a	Do (Mo)	+++	++
<i>Echinochloa colonum</i>			-	-
<i>Eleusine indica</i>	a		-	-
<i>Eragrostiella bifaria</i>	p	Do	++	++
<i>Eragrostis gangetica</i>	a	Mo (Do)	++	++
<i>Eragrostis tenuifolia</i>	p	Do	++	++
<i>Eragrostis unioloides</i>	a	Mo (Do, Ds)	++	+
<i>Eragrostis viscosa</i>			-	-
<i>Eulalia trispicata</i>	p	Do (Mo, Ds)	++	++
<i>Hackelochloa granularis</i>			+	+
<i>Hemarthria compressa</i>	p	Mo	-	-
<i>Heteropogon contortus</i>	p	Do ((Mo, Ds)	+++	+++
<i>Imperata cylindrica</i>	p	Ds	-	-
<i>Isachne globosa</i>	p		-	-
<i>Ischaemum indicum</i>		Mo (Do, Ds)	++	+++
<i>Ischaemum rugosum</i>	a	Mo	++	++
<i>Iseilema prostratum</i>		Mo (Do)	++	++
<i>Manisuris clarkei</i>	a	Mo	++	++
<i>Mnesithea laevis</i>	p	Do (Mo, Ds)	+++	+++
<i>Narenga porphyrocoma</i>	p	Mo (Do, Ds)	++	++
<i>Oplismenus burmannii</i>		Ds	+	++
<i>Oryza minuta</i>			-	-
<i>Panicum austroasiaticum</i>		Ds (Do)	+++	++
<i>Panicum montanum</i>	p		-	-
<i>Paspalidium flavidum</i>			-	-
<i>Paspalum longifolium</i>		Mo	-	-
<i>Pennisetum hohenackeri</i>			-	-
<i>Pennisetum setosum</i>	a		-	-
<i>Phragmites karka</i>	p	Ws (Mo)	-	++
<i>Pseudopogonatherum contortum</i>	a	Mo Do	+	+
<i>Pseudosorghum fasciculare</i>		Ds	-	-
<i>Rottboelia exaltata</i>	a		-	-
<i>Saccharum spontaneum</i>	p	Do, Ws (Mo, Ds)	+++	+++
<i>Sacciolepis indica</i>		Mo (Do, Ds)	++	++
<i>Sacciolepis myosuroides</i>		Mo	++	-
<i>Schizachyrium brevifolium</i>	a	Do (Mo, Ds)	+++	+++
<i>Sehima nervosum</i>			-	-

Species		Occurrence	Frequency	
			Kanha Meadow	Other meadows
<i>Setaria glauca</i>	a	Do (Mo, Ds)	+++	++
<i>Setaria tomentosa</i>			-	-
<i>Sorghum halepense</i>	p	Ws	-	++
<i>Sorghum nitidum</i>		Mo (Do, Ds)	++	+++
<i>Sporobolus diander</i>	p	Do	++	++
<i>Themeda arundinaceae</i>	p	Mo	-	-
<i>Themeda quadrivalvis</i>	p	Do (Ds)	++	+++
<i>Themeda triandra</i>	p	Mo, Ds (Do)	++	+++
<i>Vetiveria zizanioides</i>	p	Ws (Do, Mo)	++	++
CYPERACEAE:				
<i>Cyperus compactus</i>		Mo	-	-
<i>Cyperus exaltatus</i>		Ws (Mo)	+	++
<i>Cyperus iria</i>		Mo	++	+
<i>Cyperus paniceus</i>		Mo	+	+
<i>Cyperus pilosus</i>		Mo	++	+
<i>Cyperus pumilus</i>		Mo	+	+
<i>Fimbristylis dichotoma</i>		Mo	-	-
<i>Fimbristylis quinquangularis</i>		Mo	++	+
<i>Fimbristylis schoenoides</i>		Mo	++	+
<i>Fimbristylis tetragona</i>		Mo	++	++
<i>Scleria levis</i>		Mo	+	++
ERIOCAULACEAE:				
<i>Eriocaulon oryzetorum</i>			-	-

a = annual; p = perennial; Do = dry open; Mo = moist open; Ds = dry shady; Ws = wet, sandy riverbed; secondary occurrence in brackets.

Frequency	+++	: in	> 10%	of all 10m ² plots
	++	: in	1 - 10%	of all 10m ² plots
	+	: in	0,1 - 1%	of all 10m ² plots
	-	: in	< 0,1%	of all 10m ² plots